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HOW TO RESEED

SOUTHERN IDAHO RANGE LANDS

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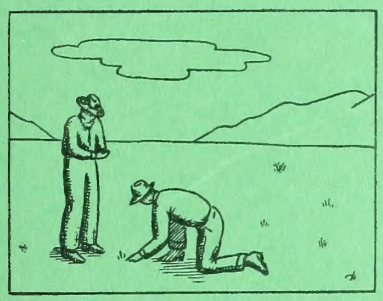

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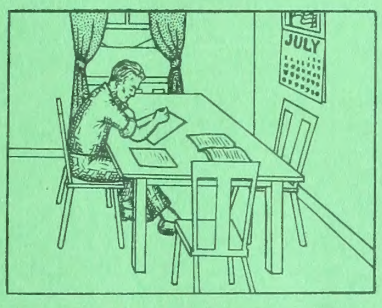

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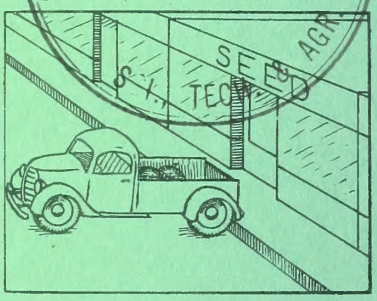
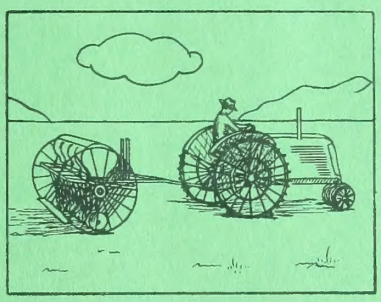
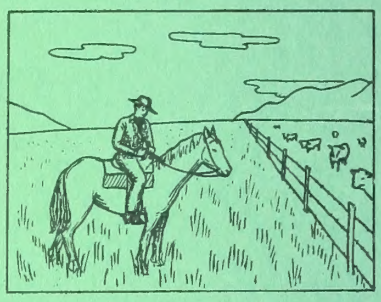


BUY SUITABLE SEED

MAKE CORRECT MIXTURES



USE EFFECTIVE METHODS



MANAGE WISELY

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

REED W. BAILEY, DIRECTOR.

OGDEN, UTAH.

JUNE, 1943.

Range reseeding can increase the forage production on many acres of southern Idaho range lands. Careful planting by proper yet inexpensive methods will produce good stands on many lands now covered with annual weeds, cheatgrass, or brush, and where mountain valleys or burned timber tracts need revegetating.

Sufficient knowledge about suitable species, methods of planting, and site requirements has been acquired to justify formulation and prosecution of a reseeding program for certain range lands of southern Idaho.

HOW TO RESEED SOUTHERN IDAHO RANGE LANDS

By

A. C. Hull, Jr., and C. Kenneth Pearse 1/

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Additional low-cost forage is greatly needed by the range livestock industry of southern Idaho. Reseeding of depleted tracts by proper methods will help supply this forage. Where the value of the increased forage will repay the cost of planting, reseeding of selected sites is justified.

The important part that reseeding can play in restoring ranges to a fuller production has been sufficiently demonstrated to justify a reseeding program. Satisfactory results can be obtained on many sites during average or better years, although more study is needed to insure consistent success under all conditions and to extend reseeding to all ranges where it is needed. Present information, even when correctly applied cannot eliminate failures. However, the chances for success will be best if recommended procedures are applied with discrimination and close attention is given to details.

1/ Assistant Forest Ecologist and Conservationist, respectively, of the Intermountain Forest and Range Experiment Station, Ogden, Utah.

The experiments which have helped clarify these principles have been carried out in widely separated points in Idaho. Work has been centered near Dubois, near Idaho Falls, near Holbrook, and on and near the Boise National Forest. Observations throughout the southern part of the state on other test plantings and on large-scale plantings by public agencies and livestock men have substantiated experimental results.

Several specific phases of the reseeding problem are being studied. The suitability and value for range reseeding of almost 250 species are being tested and some species have been found adapted to each of the problem areas covered in this report.

The efficiency of many methods of seedbed preparation and planting has been tested. These include railing, plowing, disking, harrowing, burning, drilling, and broadcasting with and without various methods of covering on prepared and unprepared ground, on snow, and on ashes. Plantings have been made at all practicable seasons of the year, and at various rates, row spacings, and depths.

In each test the nature of the soil, climate, and vegetation has been recorded to serve as a guide for future plantings and for recognizing tracts on which similar results can be expected.

The principles which have thus been developed and which must be recognized for successful reseeding of range lands are as follows:

⇨ Reseed the better sites first.

The best stands are secured where the soil is deep, fertile, and where the moisture supply is above average. Poor soils or rough sloping lands should be avoided until after the better sites are seeded. A good indicator of productivity and the chance for successful reseeding is the vigor and density of the existing low-value vegetation. Dense, vigorous stands of sagebrush and other low-value vegetation are usually produced on good sites, and therefore denote sites favorable for reseeding. Proper seeding of productive land increases the range forage supply more than does similar effort applied either to less productive land or to a larger area by less effective methods.

⇨ Choose adapted species.

Only those species should be planted which are well adapted to the soil, climate, and can maintain a good stand and yield a continuous, worthwhile volume of forage under proper grazing use. Learn as much as possible about the growth requirements of suggested species as well as the growing conditions where they will be planted. Seed grown locally or under similar climatic conditions should be used whenever available.

⇨ Use mixtures wherever possible.

Mixtures take advantage of local soil and moisture differences better than do single species. Therefore, and because of differences in seasons of growth, they provide more forage and a longer grazing season. Grazing of new stands can be started sooner if adapted fast-growing species are included in the mixture. Fast- and slow-growing species or species of different growth habits, seeded in alternate drill rows, do not compete so directly with one another in the seedling stage.

⇨ Use sufficient seed but avoid overseeding.

Correct seeding rate is dependent upon the efficiency of the method of seeding and the purity, germination, and size of the seed used. The use of excessive seed is not only wasteful, but also may result in failure due to competition for moisture among the seedlings.

Recommended seeding rates are based on good seed and efficient methods of planting, such as drilling. When the seed is of poor quality or ineffective planting methods must be used, the rate of seeding should be increased.

Since standards of purity and germination for seeding of most species used in range reseeding have not been set up, the buyer should examine the seed for purity and soundness. Germination tests, which may be made by the State Seed Laboratory, are desirable. Good seed with a purity of 98 percent and a germination of 95 percent (live seed content of 93.1 percent) is a better buy at 15 cents per pound than is fair seed with a purity of 85 percent and a germination of 70 percent (live seed content of 59.5 percent) at 10 cents per pound. Excellent values may often be obtained in good locally grown seed or in any good seed containing chaff, straw, or other foreign material which may be successfully sown with the seed. However, the cost of removing all foreign material that would hinder drilling should be investigated before purchase.

⇨ Plant at the proper season.

On southern Idaho range lands the best season for seeding is the fall of the year. Seedlings that develop just after a continued supply of fall moisture is assured, grow during both the fall and spring seasons and are better able to withstand the summer drought than are spring-seeded species, which have less well-developed root systems. Although spring planting on well-prepared, firm seedbeds has given good results, the difficulty of getting on range lands early in the spring, combined with a short planting season and undependable moisture make large-scale spring seedings undesirable.

On high mountain lands with considerable early fall moisture, planting may begin in September. At lower elevations where fall rains can be depended upon, planting in October is recommended. Where fall rains are uncertain planting should be delayed until late fall. If at any time rains have been sufficient to assure germination and seedling survival up to the time winter sets in, seeding can be safely done.

⇨ Cover seed adequately.

Correct depth of seed covering is roughly proportional to the size of the seed. Seed of most species should be planted one-half inch deep. Small seeded species should not be covered more than one-fourth inch. Deeper covering is desirable on light, sandy, or dry soils and shallower covering on heavy clays.

The moisture supply for uncovered or shallowly covered seed is usually so uncertain that germination is poor or the young seedlings die before the roots can reach a more dependable source. Broadcasting without proper covering is successful only where moisture conditions are unusually favorable. Bulbous bluegrass, which often does well when broadcast without covering, is an exception. Seedlings of this species become dormant during dry periods and resume growth with the advent of moisture.

⇨ Reduce competition from undesirable plants.

Undesirable plants which use much of the available moisture prevent the establishment of high-yielding stands of reseeded species. Therefore, it is necessary to reduce dense stands of such plants as sagebrush or cheatgrass[2/] which would compete directly with the species to be planted. Lands supporting Russianthistle, mustards, and other summer-growing annuals usually require no treatment before planting.

⇨ Apply wise range management.

Seedlings should be grazed lighly or not at all until they are large enough to withstand grazing which is usually after the first seed crop is produced. Because grazing slows up development, plants that are continually eaten off do not reach maximum forage production as quickly as plants that are protected or only lightly used until after the first seed crop. Thus forage taken during the early life of a reseeded stand is usually obtained at the expense of a good stand or of total forage production in later years. Early protection and light grazing of reseeded stands on steep slopes or loose soil is especially important. After the plants are established, the reseeded area should be managed in such a manner as to prevent deterioration of the forage or soil.

2/ Cheatgrass (Bromus tectorum) is also referred to as cheatgrass brome, broncograss, or junegrass.

PRECAUTIONS TO OBSERVE

Haphazard planting on poorly selected areas will seldom result in satisfactory stands. Effort should be applied only where sizable and lasting benefits can be obtained. Consider carefully the following questions before planting a particular tract:

⇨ Is reseeding needed to improve this range?

If enough good forage plants are still present and only better management is needed to bring about natural recovery of the native forage, reseeding is seldom justified. First consideration should be given those low-forage producing ranges on which all or most of the valuable plants have disappeared.

⇨ Is precipitation sufficient?

Moisture supply is one of the most important points to consider in deciding whether or not to reseed an area. Usually an annual precipitation of at least 10 inches with at least 3 inches falling during the spring growing season is required.

⇨ Are the soil and topography suitable?

Ranges with productive soils yield quicker and surer returns than do unproductive areas. The more favorable tracts will make greater returns for each dollar spent and should on that account be treated before the poorer tracts. Slopes too steep for the operation of machinery ordinarily used for planting are costly to seed and reseeding operations may start erosion. The reseeding of steep slopes is not recommended except where erosion is excessive or where watershed protection is needed and then special methods must be employed to check erosion.

⇨ How will reseeding affect the year-round forage supply?

Reseeding can be especially valuable to the livestock industry by providing forage at the season when it is most needed and thereby relieving grazing on ranges which have been suffering because of improper season or intensity of use. For example increased forage on spring-fall ranges may solve a problem of overuse on summer ranges by permitting a shorter grazing season. Reseeding of spring-fall ranges with early growing grasses will supply much needed early spring feed and thus reduce the period of winter feeding.

⇨ Can the correct management be applied after planting?

Where reseeding is necessary, the original causes of range depletion should be corrected and good management should be applied. Reseeded stands will be damaged by overstocking, too early grazing, or undue concentration just as surely as were the original stands.

Reseeding will most likely be successful if the foregoing principles are carefully applied. The following recommendations are based upon the best available information and can be applied with considerable confidence.

RECOMMENDATIONS FOR RESEEDING SOUTHERN IDAHO RANGE LANDS

These recommendations are presented in a specific manner, but since they cover broad problem areas it may be necessary to modify them in accordance with local growing conditions and facilities for doing the work. Such modifications, however, should conform to the foregoing principles.

Plains, Valleys, and Low Foothills

Plains, valleys, and low foothills which can be successfully reseeded occur principally in a broad belt from Ashton to Weiser, along the Snake River and in adjacent and tributary valleys.

The original cover was chiefly sagebrush and grass with smaller areas of greasewood, shadscale, and winterfat.3/ Because of past overuse and fire, sagebrush has increased on many areas and the valuable forage plants have been replaced by inferior forage species such as cheatgrass, Russianthistle, and mustard. Reseeding can be applied on lands supporting: (1) Russianthistle and mustard, (2) dense stands of cheatgrass, and (3) dense sagebrush stands.

Stands of Russianthistle, mustard, and other summer-growing annual weeds which result from recent burning or cultivation and abandonment, are as a rule exceptionally favorable for reseeding. Such weeds do not seriously compete with the reseeded species and they are frequently beneficial in protecting the seedlings. It is desirable to plant these lands before they are occupied by cheatgrass or sagebrush, both of which make reseeding more difficult.

1. Treatment before planting. None needed.

3/ Winterfat (Eurotia lanata) is often called white sage.

2. Seed mixture.

Species	Average to dry soil and moisture. Usually at low elevations (pounds per acre for drilling)	Good soil. Rainfall considerably higher than on low plains and valleys (pounds per acre for drilling)
Crested wheatgrass*	4	4
Bulbous bluegrass**	3	2
Big bluegrass	-	1
Tall oatgrass or mountain brome	-	3
Total	7	10

*Should always be part of the mixture.
**Not recommended for southeastern Idaho.

3. Planting.

A. Season. Fall.

In localities where fall rains can be depended upon, planting in September or early October is best. Where fall rains are uncertain, later planting is better.

B. Method. Disk drill or lister drill in rows 12 or 14 inches apart. On steep, rough, or rocky land where a drill cannot be used, broadcast seed at 1½ times the rate specified for drilling and cover with disk, self-clearing, or spiketooth harrow.

On steep slopes a small sidehill drill with outrigger wheels is useful for planting either contour strips or solid stands.

C. Depth. One-half to three-fourthsinch.

Dense stands of cheatgrass result from burning or from cultivation and abandonment. These stands are most extensive on the Snake River Plains and on the granitic slopes of southwestern Idaho. Cheatgrass stands so completely utilize the soil moisture that they must be reduced in density and vigor before reseeding.

Burning cannot be depended upon for effective reduction of cheatgrass. Where scattered brush, high winds, or other conditions make cheatgrass burns exceptionally hot or where burns occur early in the summer season, the cheatgrass stand is sometimes reduced enough to allow successful planting. However, this reduction is not reliable, especially if sufficient rain causes cheatgrass seed to germinate in the early fall.

1. Treatment before planting. Kill most of the cheatgrass.

   Plow with a Wheatland or moldborad plow in the spring. Best kills are obtained if plowing is done when the surface soil is dry and before the cheatgrass seed heads are out. Disking or spiketooth harrowing is usually inadequate.

   A less positive but sometimes more practical time for this operation is in the fall after cheatgrass has germinated.

   Partial elimination of cheatgrass which may prove adequate may be obtained by fall planting with the deep furrow lister drill.

2. Seed mixture. Same as for Russianthistle and mustard (p. 6).

3. Planting. Same as for Russianthistle and mustard (p. 6).

   Deep furrow planting, which cuts out a narrow strip in cheatgrass areas thereby reducing competition, has at Dubois produced successful stands of crested wheatgrass for four consecutive years. The seed, sown after cheatgrass had begun fall growth, was planted and covered lightly in the bottom of a 2-inch furrow made by a single disk drill. In the first season wheatgrass seedlings grew alone in the bottom of the furrows. During the second growing season cheatgrass was present in the stand with crested wheatgrass, but by the third or fourth season most of the cheatgrass was eliminated.

Dense sagebrush stands in which the palatable plants have been largely eliminated or replaced by sagebrush are an important range problem. Such low-yielding ranges result from invasion or increase in density of sagebrush on abandoned cultivated, improperly burned, or overgrazed lands. Reseeding is difficult because the sagebrush hinders planting and competes with the reseeded species for moisture.

1. Treatment before planting. Effectively reduce the brush cover. Sagebrush can be torn up and much of it killed by Wheatland plows, self-clearing harrows, and rail drags. Wheatland plows are most effective where they can be used. Where the sagebrush is small and young, railing or harrowing often gives unsatisfactory kills.

   Planned burning is an economical means of eliminating sagebrush. Burned areas usually offer a good seedbed with little competition for the reseeded species. Many accidental burns can also be successfully and easily seeded. Burns

in need of reseeding should be seeded the year of burning before sagebrush and cheatgrass occupy the area.

The complete removal of the brush cover by burning, however, often exposes the seedlings to damage by wind and high temperatures. In any case fire should not be used where erosion is liable to be serious or where adequate fire control is not possible. Rabbitbrush, yellowbrush, and other species which sprout from the crowns or roots cannot be eliminated by burning.

2. Seed mixture. Same as for Russianthistle and mustard (p. 6).

3. Planting.

A. Season. Same as for Russianthistle and mustard stands (p. 6).

B. Method. Same as for Russianthistle and mustard stands (p. 6).

Where uprooted brush is so thick as to prevent drilling, broadcast at 1½ times the rate specified for drilling on the rough ground immediately after plowing. Soil sloughing will generally provide covering of the seed. If a seeder attachment for the Wheatland plow is not available, an extra man on the tractor or plow can broadcast seed satisfactorily on the plowed ground.

C. Depth. One-half to three-fourths inch.

Mountain Lands

Adjacent to the broad plain, valley, and foothills are mountain lands which vary greatly in soil and vegetative cover, precipitation received, temperature of their different slopes, and in elevation and topography. Because of a usually higher rainfall these lands are more favorable for reseeding than are the plains, valleys, and foothills. Although the mountain lands in need of reseeding are sometimes smaller in area than the broad, exposed plains, they are potentially productive and returns from reseeding are likely to be high. This mountain land can be conveniently divided into three classes: (1) mountain-brush lands, (2) mountain valleys, and (3) recently burned timber lands.

Mountain brush lands on which the more valuable forage plants have disappeared through unwise use occur in small tracts at low and intermediate elevations. Sagebrush is the most abundant species but higher precipitation and the presence of snowberry, serviceberry, chokecherry,

and the maple distinguished these lands from the dense sagebrush stands of the valleys and foothills. This type ranges from dry to moist slopes and flats and is generally productive. However, with the exception of brush-free openings, reseeding is difficult because the brush hinders planting and competes with the reseeded species. Slopes too steep for the operation of ordinary machinery should be avoided as erosion may result from their disturbance. The reseeding of such slopes is ordinarily necessary only where erosion is or may become excessive. Accidental burns in this type should be seeded wherever possible.

1. Treatment before planting. Same as for dense sagebrush stands in valley and foothill lands (p. 8).

   Burning should be attempted only where adequate fire control can be provided or where the erosion hazard is not high.

   On small areas of rough topography where heavy power equipment is not adapted, plow contour furrows 3 to 5 feet apart.

2. Seed mixture.

Species	Dry sites with low precipitation (pounds/acre)	Average soil and moisture (pounds/acre)	Favorable sites and exposures with good precipitation (pounds/acre)
Crested wheatgrass	4*	3*	2
Big bluegrass	1	1	1
Bulbous bluegrass**	2	2	-
Tall oatgrass or mountain brome	3	3*	4*
Smooth brome	-	2	4*
Orchardgrass	-	-	1
Total	10	11	12

*These species should always be present in the mixture. If it is impossible to obtain the other grasses, plant the (*) starred species at 1½ times the rate indicated.

**Not recommended for southeastern Idaho.

3. Planting.

   A. Season. September 15 until winter. The drier the site the later the seeding may be done.

   B. Method. Same as for dense sagebrush stands (p. 8).

On deep, moist soils a 6- or 7-inch drill spacing may be used. On contour furrows, broadcast immediately after plowing at 1½ times the rate specified for drilling.

C. Depth. One-half to three-fourths inch.

Mountain valleys are not extensive in area but because of their high potential productivity they are important to the livestock industry. As a result of heavy grazing and some cultivation, sagebrush, low-value weeds, and cheatgrass now occupy large tracts of range. Irrigation of the seeded area is often possible and results in greatly increased forage production.

1. Treatment before planting. Where sagebrush is present same as for dense sagebrush stands (p. 8). Where low-value weeds, grasses, or sedges are present, plow with Wheatland plow.

2. Seed mixture.

Species	Dry to average soil and moisture. Summers often dry. (pounds/acre)	Soil and moisture favorable for continued growth of plants during summer (pounds/acre)
Crested wheatgrass	2	-
Tall oatgrass or mountain brome	4*	4*
Smooth brome	3*	4*
Slender wheatgrass	2	2
Orchardgrass	1	2
Timothy	-	2*
Total	12	14

*These species should always be present in the mixture. If other grasses cannot be obtained, plant starred species at 1½ times the specified rate.

3. Planting.

A. Season. Late summer through late fall, depending on when rainfall can be expected.

B. Method. Drill if practical with 6- or 7-inch row spacings.

Where plowing has been necessary, the seed may be broadcast immediately following plowing at 1½ times the rate specified for drilling. Where soil sloughing will not cover the seed it should be covered by harrowing or brush dragging.

C. Depth. One-half to three-fourths inch.

Recently burned timber lands occur in two widely separated areas: in the ponderosa pine-Douglas-fir type of southwestern Idaho and in the lodgepole pine and Douglas-fir types of southeastern Idaho. Immediate reseeding is often desirable for erosion control. Lack of plant competition and ease of seed covering are additional advantages gained by early treatment. Logging roads and skidways on cut-over tracts present similar conditions and can be planted in the same manner.

1. Treatment before planting. None needed if planting is done the year of the burn.

2. Seed mixture. Because of wide variations in elevation, moisture, and soils, the mixtures for reseeding can best be selected from previously discussed areas of similar growing conditions (pp. 7, 10, and 11). Some suggested mixtures are as follows:

Species	Southwestern Idaho		Southeastern Idaho
	Dry sites with low precipitation (pounds/acre)	Good soil and moisture, usually higher elevations (pounds/acre)	Usually high elevations (pounds/acre)
Bulbous bluegrass	2	-	-
Crested wheatgrass	3	2	-
Big bluegrass	1	1	-
Tall oatgrass or mountain brome	2	4	4
Smooth brome	2	3	4
Orchardgrass	-	1	2
Timothy	-	1	2
Slender wheatgrass	-	-	2
Total	10	12	14

3. Planting.

A. Season. Late summer through late fall depending on when rainfall can be expected.

B. Method. Broadcast in the ashes: where seed will not be covered by ashes, brush dragging may help if disking or harrowing is not possible.

C. Depth. One-half to three-fourths inch.

SPECIES USEFUL FOR RANGE RESEEDING IN SOUTHERN IDAHO

Species cited in the recommendations

Only species that have been well tested and for which seed is commercially available for large-scale range reseeding have been included in the recommended mixtures. These species are described below:

Big bluegrass (Poa ampla), a fast-growing bunchgrass, occurs natively in southern Idaho. It is best adapted to reseeding the more fertile soils of the plains, valleys, and foothills, and mountain brush zones. It establishes itself quite easily and produces a large amount of palatable forage and an abundant seed crop. It grows very early in the spring and ordinarily renews growth again in the fall. Big bluegrass seedlings are easily pulled out of the ground and stands should not be grazed until the roots become well established. Seed is now available at some commercial firms but the price is still comparatively high. Because there are nearly one million seeds in a pound, low seeding rates are effective.

Bulbous bluegrass (Poa bulbosa) is the most generally successful species for seeding the drier sites on the plains, valleys, foothills, and lower mountains of southwestern Idaho. In this section it will slowly but successfully invade areas now occupied with cheatgrass. Because the seedlings go dormant during dry weather and revive with moisture, this species is able to produce good stands without seed covering. Bulbous bluegrass is a shallow-rooted bunchgrass which grows early in the spring, produces seed (bulbils), and dries up about the same time as cheatgrass. Although the forage is low in volume it is high in palatability and is useful for mixtures where early spring feed is needed. This species is valuable for seeding on lands too poor in moisture-holding capacity to support higher yielding species and where seed covering, necessary for the success of other species, is not feasible.

Mountain brome (Bromus carinatus), a native of southern Idaho, is one of the better species for seeding mountain and foothill ranges where the soil is good and the precipitation is above 15 inches annually. Mountain brome is a tall bunchgrass which produces a large amount of palatable forage. Although comparatively short-lived, it produces an abundance of large seed and reseeds itself readily. On adapted sites it is aggressive and spreads rapidly. Considerable forage and a small seed crop is often produced the first growing season. Seed has quite recently become available. Locally grown seed is preferable.

Smooth brome (Bromus inermis) is hardy, aggressive, long-lived, and forms a dense sod by means of many rootstocks. It is widely used for irrigated pastures and is one of the most successful species for reseeding all mountain, foothill, and valley land where the soil is

good and precipitation is above 18 inches a year. Smooth brome is resistant to grazing and produces a great abundance of highly palatable, leafy forage. The early spring growth is of value for early grazing. Although comparatively slow to become established, good stands are usually secured.

Tall oatgrass (Arrhenatherum elatius) has been one of the more successful species on valley and mountain range lands where annual precipitation is above 15 inches. It does moderately well on poor soils. Good stands are easily obtained and when once established it usually reseeds itself readily. Tall oatgrass is a deep-rooted bunchgrass which produces a great abundance of palatable forage. Rapid development and early spring growth make it useful in mixtures. The light, fluffy husk around the seed and the awn prevent even distribution when drilled unless the seed has been run through a hammer mill.

Orchardgrass (Dactylis glomerata) is readily established and produces good stands at intermediate and high elevations where the soil remains fairly moist during most of the summer season. Once established it is capable of withstanding extended periods of drought. It produces excellent stands when seeded in partial shade and it reseeds itself very readily.

Orchardgrass is a long-lived, deep-rooted, densely tufted bunchgrass which is resistant to grazing. It starts growth early in the spring and produces a medium amount of palatable forage.

Timothy (Phleum pratense) is well adapted for reseeding mountain meadows and sites where the soil does not dry out for long periods during the summer. It is shade-tolerant and grows well under aspen, conifers, or brush. Timothy becomes established quickly and reseeds itself readily. This species produces an abundance of highly palatable forage and will withstand moderate grazing. Seed is cheap and as there are more than one million seeds per pound not much is needed to produce a good stand.

Crested wheatgrass (Agropyron cristatum). This hardy, long-lived deep-rooted bunchgrass is the most generally successful species for seeding plains, valleys, and slopes of southern Idaho having low or medium rainfall. Good stands have been produced on well-drained soils ranging from clay to sand at elevations from 2,000 to 7,000 feet. It grows very early in the spring and is best grazed at that time.

Although slow to establish a stand it produces an abundance of moderately palatable forage and a good seed crop, even under adverse climatic conditions.

Fairway crested wheatgrass, a fine-leaved strain, is preferred by some growers, but it is not superior for range plantings.

Slender wheatgrass (Agropyron trachycaulum) is a deep-rooted bunchgrass found native in Idaho under a wide variety of soil and moisture conditions. For reseeding it is best adapted to higher elevations where the precipitation is above 20 inches. Good palatable stands are produced through reseeding but the rate of maturity is moderately slow. The amount and leafiness of the forage, drought-resistance, winter-killing, and rate of development vary greatly, depending upon the source of the seed. For this reason it is best to buy seed which is grown under conditions that approach, as nearly as possible, the conditions under which it will be planted.

Other useful and promising species

Of the 250 species that have been tested for range reseeding, many have proved useful under limited conditions. Others promise to be widely useful but have not been adequately tested. Still other species which are definitely useful for range reseeding await the development of a commercial source of seed. The most promising of these species are described below and may well warrant trials by individuals interested in range reseeding:

Alfalfa (Medicago sativa) has produced satisfactory stands when seeded on the dry and moderately moist ranges of southern Idaho. Once established it is drought-resistant but its use for range reseeding is limited by the fact that it does not withstand grazing well. Being a legume it benefits the grass mixture by adding nitrogen to the soil. Seed should be inoculated before seeding on range lands where alfalfa has not been previously grown.

White clover or white dutch clover (Trifolium repens) has been found useful for reseeding mountain lands where the soil is rich and where the rainfall is high or supplemental irrigation is possible. Plants spread rapidly by stolons and will withstand heavy grazing. It is best used in a mixture with grasses and as there are three-quarters of a million seeds per pound not much seed is needed for a good stand.

Idaho fescue (Festuca idahoensis), a native bunchgrass, should prove to be useful as part of a mixture for seeding lands of medium to high rainfall. Once established it can withstand extended periods of drought. Seed is not available on the market.

Meadow fescue (Festuca elatior) is a deep-rooted bunchgrass well suited for reseeding moist, slightly alkaline valley lands and moist mountain ranges. It is fast-growing, productive, palatable to all classes of stock, and will withstand heavy grazing use. It is best used in mixtures with more aggressive, longer lived species.

Sheep fescue (Festuca ovina) a small, long-lived bunchgrass, native of Idaho, may be used for reseeding ranges having intermediate to high rainfall. Sheep fescue is rather slow to become established

but good stands are usually secured. It is able to withstand close grazing. Seed is expensive, but as there are more than one-half million seeds per pound, not much is required for a stand.

Indian ricegrass or sandgrass (Oryzopsis hymenoides), a native of Idaho's arid regions, is useful for reseeding the light-textured or sandy soils in the low rainfall areas of southern Idaho. Even on the dry or desert ranges where it grows, it provides a considerable quantity of palatable forage. This deep-rooted, long-lived, drought-resistant species is slow to develop under the adverse conditions where it is most useful. Seed planted one fall may germinate that fall, but it usually germinates in the fall of the next year or in the spring of the second year. Seed scarified by acid or mechanical means will germinate sooner but as yet no large-scale scarification method has been developed. Seed is available at some dealers but because of the limited supply it is expensive. Native stands of this species may be harvested with a combine and good seed obtained.

Winter rye (Secale cereale) has proved valuable for furnishing quick forage on many valley and foothill lands. Rye pastures are good sources of temporary feed but rye cannot take the place of perennial plants. Rye is more drought-resistant than wheat and is capable of growing on dry, poor soils but is most useful on sites similar to those used for dry farming. The ground should be prepared as recommended for seeding perennial grasses at the same sites. Rye drilled at 25 to 35 pounds per acre at 1 to 1½ inches deep in early fall will usually furnish considerable forage the following spring. Since rye is an annual and depends entirely upon seed for the continuation of the stand, it must be permitted to make seed heads or else be planted every year. When rye stands are allowed to reseed they may remain productive several years, especially when disked or harrowed during the recommended planting season.

Michels rye, Michels grass, or Michels hybrid has much the same growth habit and adaptation as winter rye. Where seed can be obtained at a nominal cost this species may be used in the place of rye at the rate of 20 to 25 pounds per acre. Individual plants of this form seem to stool out more than rye and some of them live more than one year, but even these are not strongly perennial.

Yellow sweetclover or yellow blossom sweetclover (Melilotus officinalis). This tall-growing clover is useful for reseeding lands of medium to high rainfall. Once established it grows rapidly and is fairly drought-resistant. It is well adapted to moderately moist alkaline soils. Sweetclover is a biennial, producing seed in the second growing season, and depends upon this seed crop for its continued existence. When soil moisture is good it will produce volunteer stands for several years but it does not reseed itself well on packed or dry soils, especially where competition with other species is severe. Sweetclover is advantageous in a grass mixture as it

develops early, adds nitrogen to the soil, and provides a variety of feed. When it is sown alone there is always a danger of bloating livestock.

White sweetclover is very similar but is coarser, less drought-resistant, and not so desirable for pasturage.

Bearded wheatgrass (Agropyron subsecundum) occurs natively in Idaho and is adapted to reseeding ranges of intermediate and good soil and moisture conditions. Good stands are obtained from reseeding and plants grow rapidly, often producing seed the first year. This species is a deep-rooted, long-lived bunchgrass which produces a large amount of palatable forage.

Bearded bluebunch wheatgrass (Agropyron spicatum) and beardless bluebunch wheatgrass (Agropyron inerme), the "little bunchgrass" or "wheatgrass" of settlement days are similar in growth requirements and appearance. These native species are adapted to the low and intermediate rainfall areas of southern Idaho.

These grasses are drought-resistant, long-lived, and deep-rooted. Although slow to become established they produce considerable forage, even under adverse conditions. Because of their early spring growth they are valuable on spring ranges. Seed may be secured from dealers specializing in seed of range grasses, but the price is still high.

Bluestem or western wheatgrass (Agropyron smithii). This native grass is adapted to reseeding fine-textured, or heavy soils in the low and intermediate rainfall belts and is tolerant of alkali. It is slow to become established and although good stands have been obtained, success is dependent upon good moisture during the seedling stage. A sparse initial stand will frequently spread rapidly in the second or later years. Bluestem wheatgrass is drought-resistant, long-lived, and customarily forms an open sod. It is very resistant to grazing use and furnishes a good supply of moderately palatable feed which cures well on the stem. On adapted sites it would do well in a mixture with crested wheatgrass.

Siberian wheatgrass (Agropyron sibiricum) is similar to crested wheatgrass and appears to be adapted for much the same conditions. It is reputed to be more drought-resistant than crested wheatgrass but tests to date do not show that it excels crested wheatgrass in any respect. Seed is available in small amounts.

Stiffhair wheatgrass (Agropyron trichophorum). This recent introduction should be best suited for seeding ranges of low and intermediate rainfall. It is moderately slow to become established but often produces good seed the first year. It has vigorous rootstocks which form a heavy sod. Considerable herbage is produced even on dry sites. Seed is not yet commercially available.

Tall wheatgrass (Agropyron elongatum) is a large, vigorous, newly introduced bunchgrass which appears to be useful for seeding southern Idaho ranges of low and intermediate rainfall. It grows rapidly and produces a good seed crop and a large amount of forage which stays green late in the summer. It is reported to be well adapted to moderately alkaline soils. Seed is not yet commercially available.

Thickspike wheatgrass (Agropyron dasystachyum), a native of southern Idaho, has not been used for large-scale reseeding. It is a very drought-resistant, sod-forming species. Although tests show that it will grow on areas from the lowest to moderately high rainfall, it will probably be of most use in areas of low rainfall. Seed is not available commercially.

A newly introduced species of wheatgrass (Agropyron intermedium), appears well adapted for seeding the low and intermediate rainfall areas. It establishes itself slowly but produces a large amount of palatable forage which stays green late in the summer and should help prolong the grazing season. It produces good seed and has rhizomes which form a heavy sod. Seed is not yet commercially available.

Blue wildrye (Elymus glaucus), a deep-rooted bunchgrass, native of southern Idaho, is adapted to a variety of soil conditions at intermediate elevations where the rainfall is medium to good. It will grow well under trees and brush. It establishes itself readily, grows rapidly, and produces a good seed crop and a considerable amount of fairly palatable forage.

Seed is obtainable from some dealers and local growers but is comparatively high priced. Awns on this seed make it difficult to drill and de-awned seed should be used for drilling.

Canada wildrye (Elymus canadensis). This rapid-growing bunchgrass, a native of moist sites at low elevations, has not been thoroughly tested but appears to be useful for reseeding moderately alkaline soils and for mountain lands of intermediate to high rainfall. It develops rapidly and produces an abundance of seed and herbage. Good stands are obtained through reseeding. Seed is available in limited amounts and should be de-awned before drilling.

Russian wildrye (Elymus junceus), a fast-growing, hardy introduced bunchgrass, appears adapted to some of the drier sites at low and intermediate elevations. Good stands are easy to obtain and plants mature rapidly and produce a good seed crop and an abundance of early spring forage which is reported to be palatable to all classes of stock. It is reported to be doing exceptionally well in the Dakotas and Montana. Seed is not commercially available.

EQUIPMENT USEFUL FOR RANGE RESEEDING

Effective reseeding requires the use of effective implements and machinery. The efficiency of many types of farm and road machinery considered practical for range reseeding has been tested. Those that have been found most useful are:

Disk grain drills provide one of the most efficient methods of evenly distributing and covering seed and should be used wherever feasible. On range lands a single disk drill usually cuts through weeds and trash and does a better planting job than does a double disk drill. However, on a prepared seedbed, double disk drills with depth regulators are undoubtedly better. On steep slopes a small single disk drill with outrigger wheels is practical.

Most seed used for range seeding will feed through a grain drill if the box is but partially filled and if an agitator is used. An agitator may be readily attached to the grain box of most drills. Mixtures containing light or bearded seed may frequently clog the drill which has to be watched and the clogged seed poked into the feed mechanism by means of a stick or wire to insure feeding. Light or bearded seed should be processed in a hammer mill to remove the hulls or beards. Uniformity and ease of drilling make de-awned seed well worth the extra cost.

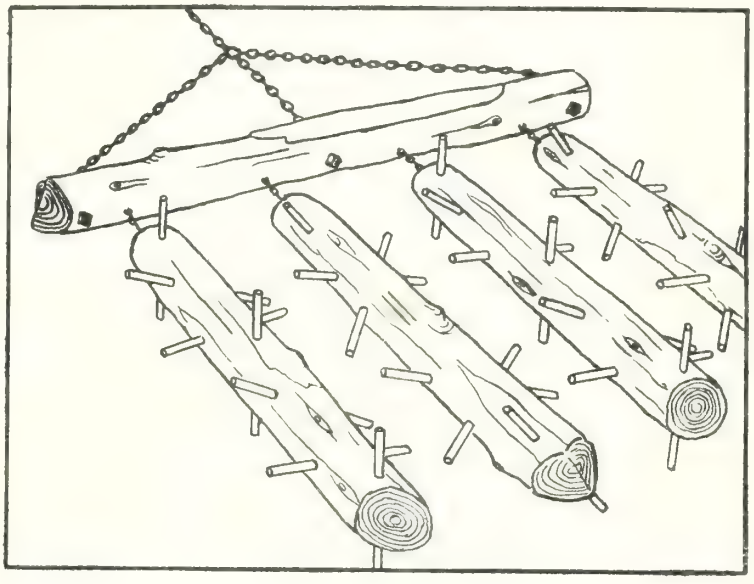
The spacing of the rows can be adjusted by plugging some of the feed spouts.

Lister drills (often called lister or shovel type deep furrow drills) plant at the proper depth in deep, broad furrows. They pull harder than disk drills but the furrows are advantageous in reducing competition and accumulating moisture.

Broadcast seeders are of various types but the most common are small "Cyclone," "Cahoon," or "Whirlwind" hand seeders and "endgate" seeders which are attached to a wagon. The seed is thrown out in a wide swath at a uniform rate by a rapidly revolving disk. They provide better distribution than hand broadcasting.

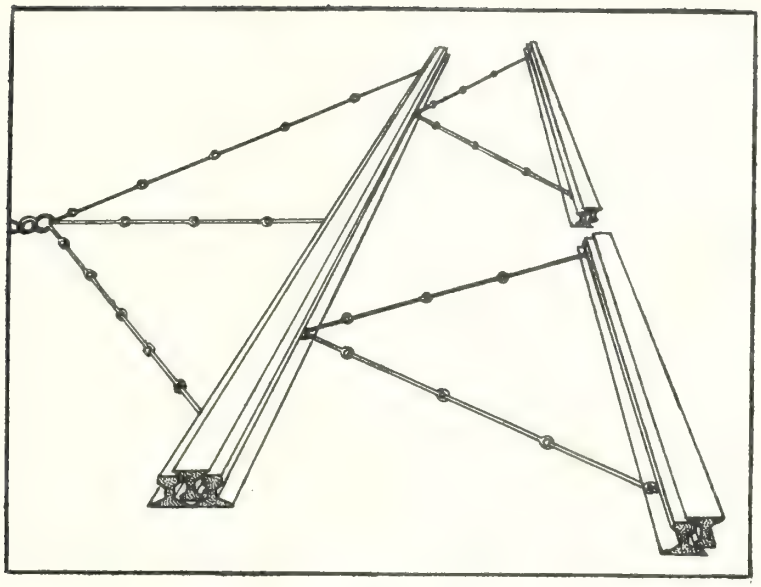
Harrows (spiketooth, springtooth, and disk harrows). Spiketooth and springtooth harrows are useful for covering seed on loose soil, but clog where weeds are abundant. Disk harrows (often called disks) are effective on hard, rocky soils and do not clog where vegetation is thick. They are satisfactory for covering seed where drilling is impossible. Heavy disk harrows have often been used successfully in killing cheatgrass or breaking down sagebrush prior to seeding.

Self-clearing harrows (log or pipe harrows, Dixie drags) are useful for removing competition and covering seed on land too brushy or rocky for farm harrows. The self-clearing harrow as shown in the sketch can easily be made from logs and short lengths of drill or other high-quality steel and short chains and swivels. It consists of 3 to 10 logs attached by one end to an evener in such a manner that they are free to rotate. Logs should be 6 to 8 inches in diameter and 8 to 12 feet long. Six to eight holes are drilled through each log in a spiral arrangement and lengths of drill steel are forced through them to provide a series of radial teeth 6 inches long. Four- to six-inch well casings filled with concrete may be substituted for the logs for greater effectiveness and durability.



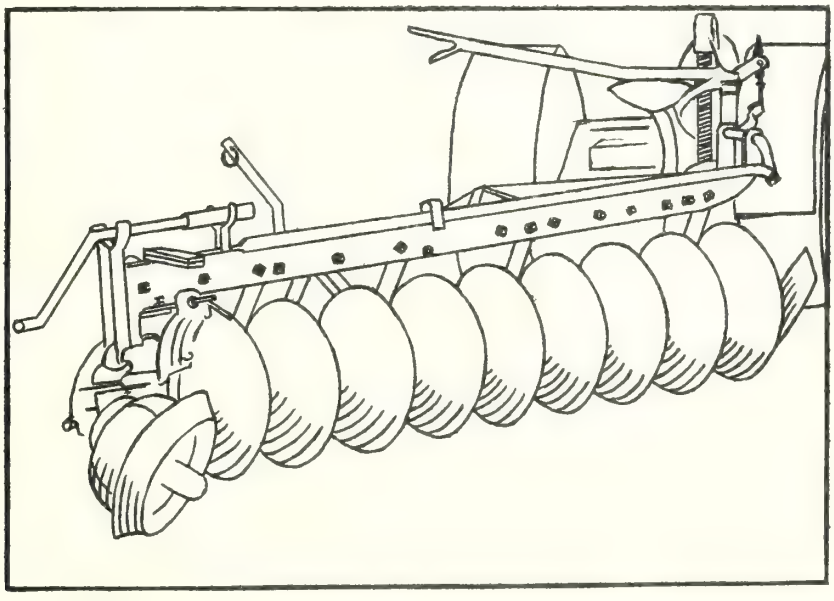
Rails. A drag of railroad rails is effective in breaking down and killing sagebrush. Drags may be constructed according to several patterns, depending upon the material and facilities available. One of the most successful is the "A" rail. The "A" rail is built like the letter "A." The two outside rails are heavy, preferably 120-pound rails, and are 30 feet long. The cross member is composed of two 90-pound rails. Two fins welded to the bottom of these cross rails cut into the ground and keep the rail from slipping sidewise.

Another rail that has been successful is shown in the accompanying figure. The front section is made from three 30-foot lengths of rail welded in the positions as indicated in the sketch. Each of the rear sections consist of two 15-foot rails welded together as shown. Three-foot lengths of 1-inch steel rods with eyes connect the front and rear sections and also run to the tractor. One-inch steel eye bolts connect the rods to the rails. On the front section the two outside eye bolts are 4 feet from the end, and are 3 feet from the end on the rear sections. The connecting rods of the rear section run to eye bolts 7 feet from the end of the front section. The distance from the tractor to the front section is 12 feet and 9 feet from the front to the rear sections.



Rail drag

Wheatland plows, also known as disk tillers, disk plows, or one-way disks, are used for plowing on dry farms. They resemble one section of a disk harrow in that the disks are all on one axis, but are much heavier and the disks are from 20 to 26 inches in diameter and are spaced from 8 to 12 inches apart. The Wheatland plow is useful in destroying sagebrush or in turning under cheatgrass or weeds prior to seeding. Seed should be broadcast behind the plow or to the side of the tractor on the previously plowed strip where it will usually be covered by soil sloughing, although harrowing is a surer means of covering seed.



Plows, both disk and moldboard, are useful in turning under weeds, cheatgrass, or small brush and loosening compact soils in preparation for seeding. Disk plows are better where brush is heavy or where rocks would damage a moldboard plow. The usefulness of both moldboard and disk plows for range reseeding is largely limited to the construction of contour furrows on sloping lands. More efficient machines have been developed for soil preparation on large tracts.

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 4 September 1943

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HAND COLLECTION AND CLEANING OF SEED OF NATIVE FORAGE PLANTS

By A. C. Hull, Jr., Assistant Forest Ecologist

Widespread interest in range reseeding has stimulated the use of native species for planting range lands. Many promising species have not been used because of an inadequate seed supply. To help overcome this seed deficiency, machinery (1-8)[1/] has been developed to facilitate collecting and cleaning seed of some native species. However, the terrain and the nature of the native stands of some western species makes hand collection the only method of obtaining clean seed for experimental plantings or seed production plots. Hand collection is also necessary on small production plots which do not justify the use of seed collection machinery.

Many methods of hand seed collection have been tried. Hand stripping or flailing the seed directly into a bucket or canvas is the simplest but usually the least efficient method available. Comblike hand strippers have been successfully used to gather seed heads of some species. Seed heads have been cut with sickles, scissors, and knives and threshed at a later date with good results. Although sometimes slow, this last method saves practically all the seed.

A pair of hand paddles provided with corrugated rubber matting for rubbing surfaces is useful for collecting small amounts of clean seed. The paddles are made of 1/4-inch plywood, 7 inches wide and 11½ inches long. A steel door-pull provides the handle which is fastened to the back with countersunk, flatheaded stove bolts. Rubber matting is glued to the face of the plywood and made secure around the edges with 1/2-inch wire brads. The most suitable rubber matting has corrugations spaced 1/4-inch apart. A canvas bag supplied with shoulder straps completes the device (Fig. 1).

The method of using the paddles varies with the growth habit of the plants and the thickness of the stand. Seed of tall-growing species may be rubbed loose and caught in the canvas bag. For low-growing

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1/ Numbers in parenthesis refer to literature cited p. 3.

species, a light metal bucket or tub or a 4' x 4' canvas is substituted for the bag. Where the stand is thick, the seed heads may be rubbed over the receptacle so that the seed is caught directly. In scattered stands, the receptacle may be placed in the center of a collection circle, and the seed from individual plants transferred to it by holding seed between the paddles. A short trial will soon show which method is best adapted to each condition encountered. The most efficient use of the paddles, and whether to rub parallel or at right angles to the culms, and the proper stage of maturity for successful collection of each species can be determined by a few trials. Where seed heads are long or of uneven height, the paddles are pulled upward on the culms as they are rubbed together to loosen the seed. (See Fig. 1.)

Seed which does not rub out well while standing may be gathered by cutting the seed heads. Where the seed in the cut seed heads is too persistent for shaking or flailing, the heads are placed on a large board covered with corrugated rubber matting and threshed by rubbing with the paddles. The board should be fastened at such an angle that the seed will fall into a tub or other receptacle. A board 18" x 30" and an ordinary wash tub have proved convenient for this work. Some species may be threshed immediately after harvesting while others must first be thoroughly dried. The board-and-paddle method has been very useful in threshing small lots of species such as Oryzopsis hymenoides and Koeleria cristata. Where pods or seed heads of species like Penstemon spp., Hedysarum pabulare, Astragalus spp., and Sphaeralcea spp. are stripped by hand, the seeds are easily loosened by using the board and paddles.

Seed gathered with the paddles or threshed with the board and paddle is usually clean enough to plant. Tests have indicated that the paddles are two to four times faster than hand stripping (table 1).

Table 1.- Amounts of seed of various species obtained from comparable stands by hand stripping and by hand paddles.

Species	Hand stripping		Hand paddles	
	No. of trials	Pounds per hour	No. of trials	Pounds per hour
Agropyron dasystachyum	1*	1.58	3	4.78
" "	1	1.03	-	-
" trachycaulum	1	2.00	1	3.00
Bromus carinatus	1	1.80	1	1.90
Festuca idahoensis	2	0.43	2	1.46
Elymus triticoides	1**	1.47	1	1.55
Average		1.25		2.96

* Grass cut with scythe and threshed by flailing on large canvas.
** Some heads collected with comb stripper and hand threshed.

The board and paddle is useful in removing awns from seed lots that are too small for practical de-awning in a hammer mill (7). Awns have been removed in this manner from seed of Stipa comata, Sitanion hystrix, Cercocarpus spp., Cowania stansburiana, Atriplex spp., Hordeum bulbosum, and similar species.

Another hand machine which has not been fully developed but which shows considerable promise is the reel collector shown in figure 2. As the reel is turned by hand, the seed is knocked loose from the seed heads into the collection bag. This machine, although wasteful of seed, is useful for collecting seed of tall-growing native species where power machinery is not practical.

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Figs. 1 and 2. General views of construction and operation of hand paddles and canvas seed collection bag (above), and reel collector (right).

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 5 September 1943

GOOD SEED FOR RANGE RESEEDING

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Basis of Seed Quality

Good quality grass seed is essential to successful artificial reseeding of range lands. Quality of seed depends primarily upon genuineness, purity, and degree of germination. Genuineness refers to freedom from adulteration with cheaper seed. Fortunately, range grass seed is seldom adulterated, although errors in labeling, due to unfamiliarity of the dealers with the species, may occur. Seed purity is the percentage by weight of uninjured pure seed of the species listed on the label. In a purity analysis seed is separated into pure seed, other crop seed, weed seed, and inert matter which includes such things as broken seed, chaff, and dirt. Germination is the percentage of the pure seed that, under normal environment, is capable of developing into normal plants.

Under ordinary conditions the buyer is not interested in either the purity or germination alone but in the amount of seed that will grow. The pure, live seed content, obtained by multiplying the germination by the purity, represents the real value of the seed. Thus seed with a germination of 95 percent and a purity of 96 percent contains 91.2 percent pure, live seed; on the other hand seed with a germination of 57 percent and a purity of 80 percent contains 45.6 percent pure, live seed or but half as much as the first lot. If there are no other differences the first lot would be worth twice as much as the second lot and would yield as many plants per square foot if seeded at half the rate.

By dividing the percentage of pure, live seed into the cost per pound the actual cost of a pound of pure, live seed can be obtained. If a price of 15 cents per pound is asked for the first lot of seed in the above example, the actual cost of a pound of pure live seed would be 15 divided by 91.2 or approximately 16½ cents. If 10 cents per pound is asked for the second lot the actual price of a pound of pure, live seed would be approximately 22 cents. When the germination and the purity are known, the buyer thus has a guide for determining the real value of the seed.

How to Tell Good Seed

Although all buyers cannot be experts in determining seed quality they can easily learn enough to make intelligent purchases. In buying seed one should consider germination, date of germination test, purity (including noxious weed seed content), seed source, and age of seed and should inspect seed for color and soundness. When purchase is by mail small representative samples of the seed in question can be secured for inspection and testing. Reputable seed dealers can be relied upon to furnish reliable information.

Bright color and clean appearance indicate good seed. Seed which is dirty, moldy, discolored, or musty either in odor or appearance should be avoided as it usually indicates that it is old or diseased, has been badly stored or was harvested under very unfavorable conditions. Poorly filled seed coats and shrunken or shriveled seed should be avoided. Seed coats should be tested with a knife, or pinched between the teeth or the fingernails to make sure that they are well-filled.

If germination is not known it can be tested by most State Seed Laboratories or the buyer can very easily test a sample himself. Count out four samples of 100 seeds each and place them without crowding between clean moist cloth or several thicknesses of paper towels in a covered dish. Since some seed requires light for germination, the cover should be a glass sheet or dish. The dish may be placed in a north window in the house where it is subject to indirect light and to ordinary room temperature. Overheating or direct sunlight should be avoided in germination tests. The cloth or blotters should be kept moist but the seed should not be allowed to stand in water. At the end of 4 to 7 days (depending upon the species) all normal germinated plants should be removed and counted. Counting should be done about twice a week until the seeds have stopped germinating. Germination may continue for three to four weeks. The total count from the four samples of 100 seeds each may be averaged for final germination. If great difference occurs among the four it would be well to run the test again.

Purity can be determined accurately only in a laboratory such as the State Seed Laboratory but the buyer can examine the sample for the presence of weed seeds, broken seed, beards, hulls, straw, chaff, dirt, and other foreign material. Such materials not only affect the cost per pound of pure, live seed, but may prevent the seed from feeding readily through a drill. Attention should be given to noxious or poisonous weed seed although these problems are not generally as serious in grass seed as in other crop seeds. Broken seeds, chaff, dirt, or inert material is merely waste but if weed seed is present it may start a noxious weed infestation. The kind of weed seed present is more important than the quantity.

Where the seed is grown is also important since plants from seed produced in different sections of the country vary widely in forage production and growth habits and in their ability to withstand drought and winter-killing. Locally grown seed usually will produce plants that are best adapted to the particular areas, although seed grown at a considerable distance but under similar climatic conditions may be entirely satisfactory.

Seed of most species useful for range reseeding may be planted the year of harvest with good results. Sometimes a higher germination is obtained if seed is stored for one or two years but this storage is of practical importance for only a few species, notably Indian ricegrass (Oryzopsis hymenoides). On the other hand, seed of most grasses decreases rapidly in germination after 3 to 5 years, and old germination tests on seed may be worthless. Whenever there is a doubt as to the age or germination of the seed a new test should be made.

The value and purity of many light, fluffy, awned, or incompletely threshed seeds can be greatly improved by running them through a hammer mill and such processed seeds are now available on the market. Where these species are to be drilled, the slight additional cost for de-awning is more than made up for in ease and uniformity of drilling and in having chaff and poor seed removed. De-awning does not impair storage qualities of seed.

Seed Characteristics and Standards

The quality of grass seed varies greatly depending on the species, maturity, and the climatic and other conditions during growth and harvest. Recognized standards of purity and germination of seed of most range grasses have not been set up. The information contained in the following discussions is based on the best available sources and should serve as a guide to seed quality. The photographs (Fig. 1) will be of value in identifying the species.

Bluegrass, big (Poa ampla). Seed of this species is harvested from native or recently planted stands in the northwestern United States. Seed is small with 900,000 seeds per pound but should be bright and well-filled. A germination of 80 percent and purity of 85 percent can reasonably be expected. Seed will retain a good viability for approximately 5 years.

Bluegrass, bulbous (Poa bulbosa). This grass produces bulbils or miniature plants in place of seed. Bulbils are produced on the seed heads and harvested and planted as "seed." They vary considerably in size, but average about 480,000 per pound. A purity and germination of 90 percent can reasonably be expected. In home germination tests bulbils may be germinated in the same manner as seed but they require low temperatures, not over 68° F., especially when freshly harvested. Bulbous bluegrass "seed" is produced mainly in the northwestern United States. The bulbils retain a good viability for 5 or more years.

Brome, mountain (Bromus carinatus) is a large-seeded species with only 40,000 seeds per pound. It is collected from native stands throughout the intermountain region and is grown commercially in the northwestern United States. In this case, the native seed is much superior as the imported northwest seed produces considerably less forage and the plants are less hardy. Germination and purity should both be 90 percent or above and good germination should be retained for about 4 years under reasonable conditions. Seed will drill better if first de-awned.

Brome, smooth (Bromus inermis). Most seed of this species comes from middle west and central states although considerable seed is now being produced in the northwestern United States. Seed maintains a good viability for 5 years and although the seed appears dark and rather fluffy it should have a clean, bright color and should be well-filled. Purity should be at least 90 percent and germinations should be 85 percent and in high quality seed should be above 95 percent. There are approximately 135,000 seeds per pound.

Oatgrass, tall (Arrhenatherum elatius) seed is difficult to harvest and to sow. Seed of this species will not feed through most drills unless it is first treated in a hammer mill. Germination percentage is usually above 80 percent and sometimes above 90 percent for about 3 years, after which it begins to drop off. Purity should exceed 80 percent. There are approximately 150,000 untreated seeds per pound. Commercial seed is grown throughout the northern United States.

Orchardgrass (Dactylis glomerata). Seed of this species should have a germination and purity of 90 percent or better. It rapidly loses its viability, and seed older than 3 years should be tested just before purchase. There are approximately 520,000 seeds per pound. Most commercial seed is produced in the central states although small amounts are grown in the northwest.

Timothy (Phleum pratense). There are more than $1\frac{1}{4}$ million seeds of this species per pound. A purity of 95 percent or above and a germination of 90 percent or above can be expected. Seed retains its viability for 6 years or more. Seed is produced mostly in the central or northeastern states.

Wheatgrass, bluebunch (Agropyron spicatum). This species and the closely related beardless bluebunch wheatgrass (A. inerme) are relatively new for reseeding and most of the seed is collected from mixed native stands or from small increase plots in the northwestern United States. Purity and germination should be above 85 percent and may exceed 90 percent. There are approximately 150,000 seeds per pound. Seed should maintain a good viability for 5 years. Seed of bluebunch wheatgrass should be de-awned before drilling.

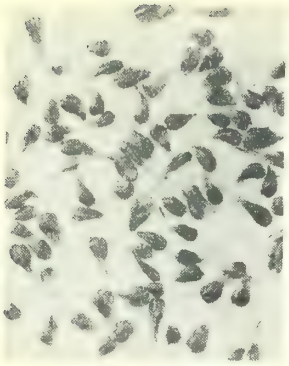
Wheatgrass, bluestem (Agropyron smithii). Seed of this species, which is also known as western wheatgrass, has a germination and purity that

is highly variable. In high quality seed both may average 80 percent or more, although in some years seed has to be used which germinates as low as 50 percent. There are approximately 105,000 seeds per pound. Correctly stored, seed will retain a good viability for 4 years. Most seed is produced in the northern Great Plains but if it could be obtained, native grown seed would be preferable.

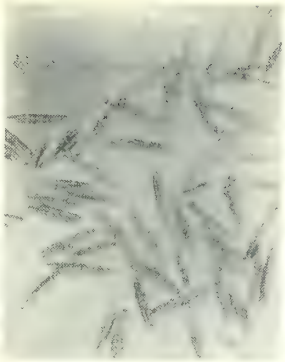
Wheatgrass, crested (Agropyron cristatum). Much good quality, locally grown seed of this species is on the market. Seed should be clean and bright. A few seeds with a greenish cast do not impair its quality. Seed should be well threshed so that all spikelets are shattered. Purity and germination should both be above 90 percent. Under proper storage seed may be expected to retain a good viability for 5 or more years. The standard strain of this species has about 210,000 seeds per pound and the Fairway strain near 400,000 seeds per pound.

Wheatgrass, slender (Agropyron trachycaulum). Seed of this species is produced mostly in the Great Plains but plants from such seed suffer from winter-killing. Best reseeding results have come from planting seed which was collected from native stands or grown locally. Both germination and purity should exceed 90 percent. Average seed retains its viability for but 3 years although some may last much longer. There are approximately 160,000 seeds per pound.

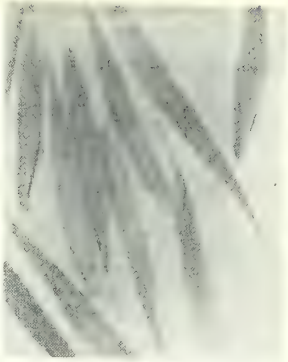
Wildrye, blue (Elymus glaucus). Seed of this species is being produced in the northwestern United States and is just becoming available on the market. Difficulty is experienced in drilling unless the seed has been de-awned. Germination and purity should be 85 percent or above but seed rapidly loses its viability and seed more than 3 years of age should be tested shortly before it is to be planted.



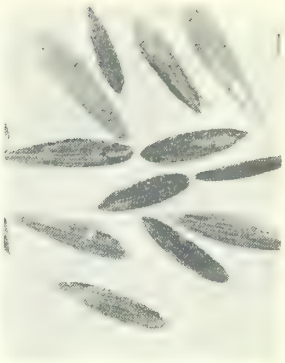
Bulbous bluegrass



Big bluegrass

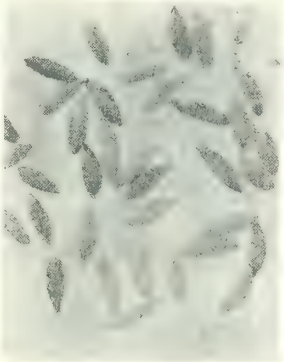


Mountain brome



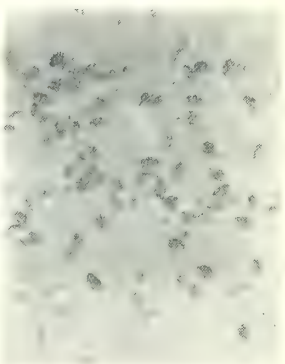
Smooth brome

Tall oatgrass



Tall oatgrass (de-awned)

Orchardgrass



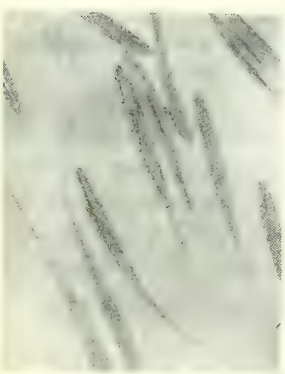
Timothy

Bearded bluebunch wheatgrass

Bluestem wheatgrass

Crested wheatgrass

Slender [illegible]grass



Blue wildrye

Fig. 1. Seeds of 12 grasses commonly used in range reseeding.

Scale, inches.

Blue wildrye (de-awned)

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 8 May 1944

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AN EFFICIENT METHOD OF BROADCASTING RANGE GRASS SEEDS

By Joseph H. Robertson, Asst. Forest Ecologist

A new method of mechanically broadcasting grass seed was given field trials in 1943 on range land in northern Nevada. An examination of each seeded area disclosed moderately uniform distribution of seed. Seeding by the new method is more rapid and costs are materially reduced in comparison with hand methods of broadcasting. Although drilling is a more efficient method of seeding, physical conditions of range land limit its use so that broadcasting is often necessary.

Description of Power Seeder

Mr. B. W. Mabee of Elko, Nevada made available for experimental seeding the numerous types of power spreaders devised by the Bureau of Entomology and Plant Quarantine to scatter bait for poisoning insects. Two of the three types tested on range reseeding projects were found suitable.

The most satisfactory type consists of a hopper from which seed falls through slots, the size of which is adjustable, into a blower driven by a small gasoline motor. The hopper, blower, and motor are mounted on an angle-iron frame, the whole unit weighing 120 pounds. With a bladelike agitator attached to the end of the blower shaft just above the slot feed, it is possible to control the rate of seed flow more precisely than can be done with the conveyor-chain type of feed. In these tests the blower type of seed distributor scattered seeds more uniformly in a strong wind than did the rotating disk type.

The seeder illustrated in figures 1 and 2 is easily adapted for use with the various kinds of equipment employed in eradication of brush and in preparation of seedbed. It can be mounted on a tractor, as in figure 3, on a tillage implement, or in a trailer, either parallel or at right angles to the direction of travel.

On those projects where seed would otherwise be scattered by hand, this seeder can be used at a saving in wages of 25 to 50¢ per acre, depending upon the wage scale and the acreage covered. With reasonable care in adjustment it will distribute seed more uniformly and at a more constant rate than is possible by hand seeding.

Several other types of mechanical bait spreaders might be adapted for the broadcasting of seed under certain conditions. Some of these spreader are powered from a wagon wheel or through the vertically raised drive shaf of the rear-axle assembly of an automobile. Five of these homemade bait spreaders are described and illustrated in Farmers' Bulletin No. 54 of the Canadian Department of Agriculture. One of them is also illustrated in USDA Farmers' Bulletin No. 1828.

Field Tests

The seeder here recommended was used by the Humboldt National Forest in connection with a wheatland plow by mounting it on the side of a crawler-type tractor at right angles to the direction of travel. The desired seed ing rate of 10 pounds per acre was easily obtained by adjusting the slot openings to the speed of the tractor. The width to which seed was spread was controlled by adjusting the speed of the motor. Several 6-inch strips of canvas were tied to the end of the blower spout to secure uniform seed distribution over the 8-foot strip turned up by the plow on the previous round.

The same seeder was in another case mounted parallel with the direction of travel on the rear end of a wheel tractor which pulled a log harrow. In order to increase the spread of seed to the 7½-foot width of the harrow a galvanized iron "fishtail" was bolted to the bottom of the blower spout and flared upward. In a strong wind, when the spread is too great or irre ular, the fishtail should be attached to the top of the blower spout and made to flare downward.

Another bait spreader with a rotating-disk seed distributor and slot feed was thoroughly tested by the U. S. Grazing Service in the Elko Grazing Dis trict in Nevada. It was mounted on a trailer towed behind a wheatland plo The comment of Grazier Gerald F. Trescartes follows: "One of the greatest disadvantages...was seeding in the wind, but I would say that it is not to serious... No trouble was experienced with the feed plugging up, and we ad justed it for seeding 3.4 lbs. of western wheatgrass per acre, which was carried out uniformly throughout the seeding program." He mentions the fo lowing advantages, "...simplicity of design and construction which gave no mechanical trouble, also the large hopper could be filled and practically forgotten. Rough ground did not affect its operation." He makes several suggestions for improving the model, e.g., increasing the rotating speed o the disk to widen the spread of seed and to counteract wind action.

The visible feed of these seeders is a distinct advantage, as it enable the tractor operator to see at a glance whether the distributor is func-tioning. Its freer feed permits the use of awned seed and of seed which has not been cleaned thoroughly enough to use in the seeder boxes of drills, wide-track broadcast seeders, or tiller combines.1/

1/ Wheatland-type plow with seeder box attached.

Cost of Broadcasting

Theoretically, range land can be seeded broadcast by hand or hand seeder for 10 to 30¢ an acre. This is assuming a 10-foot spread at speeds of 2 to 5 m.p.h. and wages at $5.00 per day. Actually costs are rarely so low because of higher wages, or working less than 8 hours, or more important, the practice of broadcasting from heavy, slow-moving equipment.

On one project three men walking with hand seeders covered 100 acres at a cost of 36¢ per acre. On another project in 1943 two (cost 55¢ per acre) men spent 11 man-days in distributing seed on 200 acres. On two other projects the full time of a man was used in broadcasting 1.5 (cost 51¢ per acre) and 1.6 acres per hour where brush was being eradicated with a wheatland plow.

The original cost of this power seeder lies chiefly in the motor and the labor required for construction. The operating cost is 25 to 50¢ per day, and with proper servicing of the motor, amortization may be over a period of 10 years.

Recommendation

Since these machines are more capable than a man of broadcasting seed uniformly, rapidly, and economically, operators contemplating doing large-scale seeding may wish to obtain enough of them to replace hand broadcasting. If this is done, it will release manpower for such jobs as mixing seed, servicing equipment, hauling posts, or fence construction which are normally done in conjunction with range reseeding. It may make possible the initiation or continuance of work on projects where a crew of only one man is obtainable.

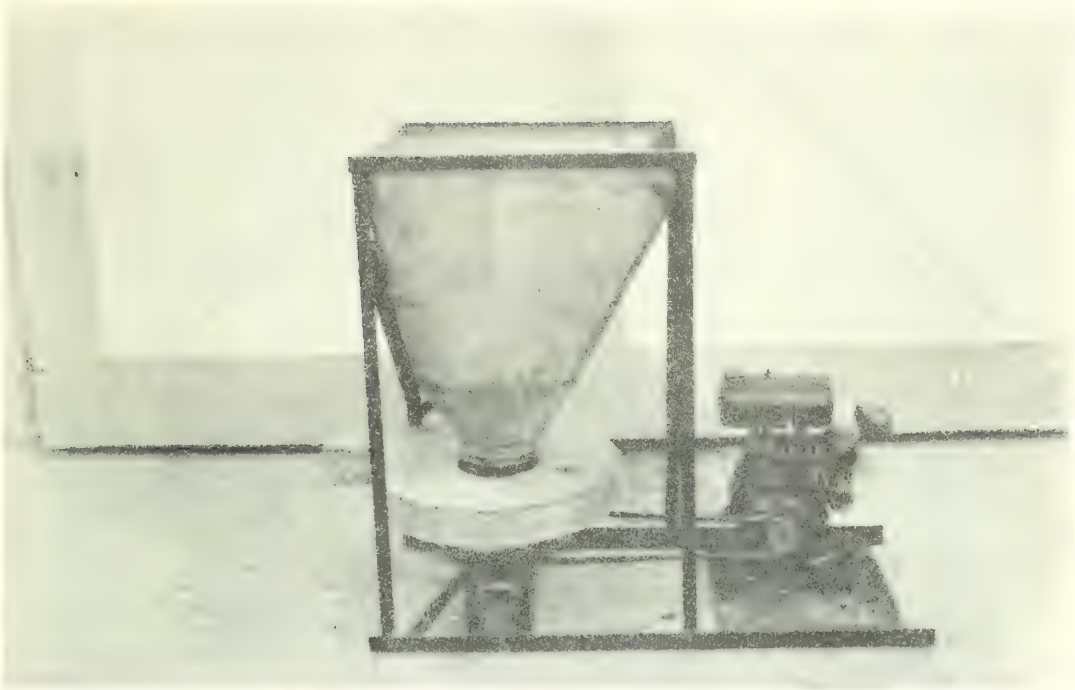

Figure 1. Side view of the best adapted type of motorized broadcast seeder showing positions of hopper, blower, and 1-horse-power motor. This device was built by the Bureau of Entomology and Plant Quarantine.

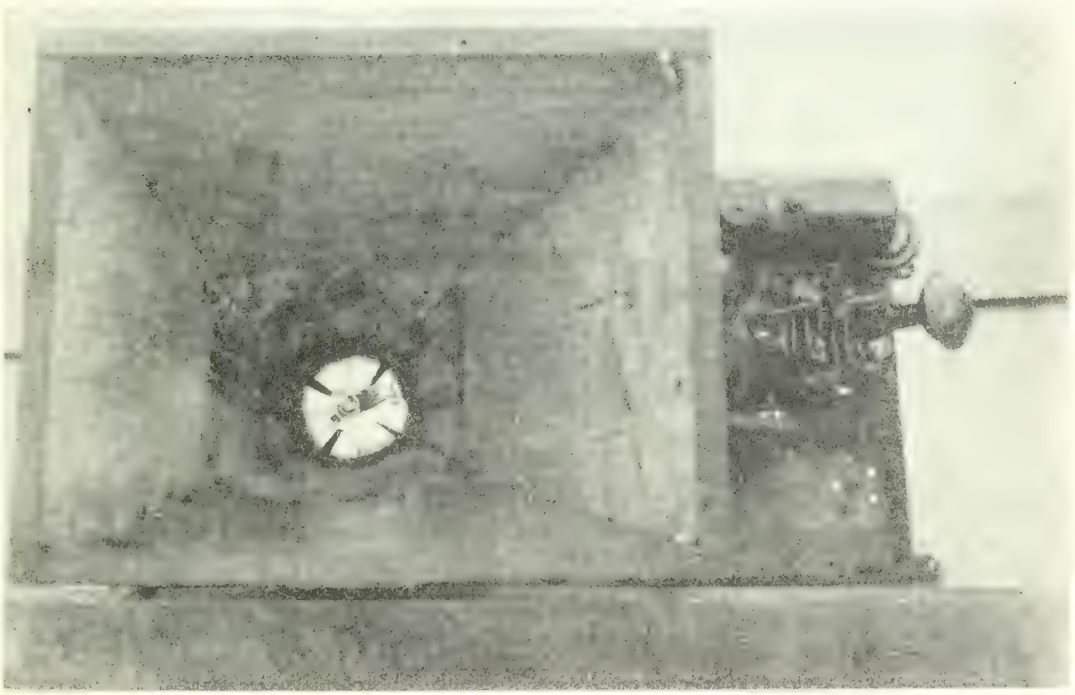

Figure 2. Interior view of the seed hopper showing the feed slots and the top of the blower shaft with seed agitator attached.

Figure 3. A motorized broadcast seeder mounted on the rear of a tractor where it is operated by the tractor driver. This seeding device was used in a demonstration planting in cooperation with the U. S. Grazing Service near Winnemucca, Nevada.

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 9 May 1944

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EXPERIMENT SHOWS VALUE OF CRESTED WHEATGRASS AND RYE FOR SPRING AND FALL PASTURAGE

By A. Perry Plummer, Assistant Forest Ecologist

It has been demonstrated that seeding depleted spring-fall ranges in the Intermountain region to crested wheatgrass or rye is highly profitable. As the benefits become recognized livestock men are anxious to apply procedures that contribute not only to the improvement of their range but also to the general well-being of their enterprise. An experiment, which consisted of grazing mother ewes and lambs on crested wheatgrass and rye pastures, and feeding on alfalfa and barley shows the value of crested wheatgrass and rye for spring-fall pasturage. The tests were conducted in 1943 by the Intermountain Forest and Range Experiment Station in cooperation with Mr. Walter Sorenson of Ephraim, in Sanpete County, Utah. The annual precipitation here is approximately 11 inches.

Prior to planting, the land had been growing only Russianthistle. The original sage and grass cover had been killed out by heavy grazing use. The soil is rocky, shallow, and of low value for cultivation, even with irrigation. Mr. Sorenson, the owner, before planting crested wheatgrass in 1940 stated:

"The land, for the grazing use I get out of it now, no more than returns the taxes."

The taxes are approximately 6 cents per acre annually.

Thirty-six common Rambouillet ewes with single lambs were divided into three comparable groups of 12 with their lambs. On April 23 one group was put in a 6-acre crested wheatgrass pasture drilled in October 1940 at a rate of 4 pounds per acre along with a mixture of other grass species. Crested wheatgrass now produces more than 90 percent of the forage. Another group was put into an adjacent 5.8-acre rye pasture which had been drilled at the rate of about 42 pounds per acre in October 1942; and a third group was placed in the feed lot on a full ration of alfalfa hay and one-half pound of barley per ewe per day. Additional sheep were put in the rye and crested wheatgrass pastures at intervals during the spring grazing period so that utilization of the respective pastures would be about what was desired. Weights were not kept on such additions, but were figured when calculating the sheep days use. Green

growth of the crested wheatgrass and rye was approximately 6 inches high. From the standpoint of the inherent productivity, the two pastures are very similar. All ewes had been on the winter range from December 15 to March 25 and were in poor condition when brought in for lambing.

All the sheep used for gain comparisons were on the three forages from the morning of April 23 to the morning of May 18, 1943 (25 days). On the latter date they were removed from all three treatments and united. From May 18 to July 1 they grazed on fields and low foothills with a band of 175 head; July 1 to October 5 they were on the Manti National Forest in a band of 1,500 ewes and a similar number of lambs. They were weighed and tagged on April 23 at the start of the treatments; weighed again May 18 at the end of the spring treatments; and again on October 11, the end of the summer grazing season. The average weights and gains for the three dates are shown in table 1.

During September, October, and the fore part of November the crested wheatgrass produced 3 to 4 inches of nutritious, green regrowth. This pasture was grazed again from November 24 to December 5 (11 days) by 21 sheep (ten ewes, ten 7-month old lambs, and one buck). No additional grazing was obtained from the rye in the fall. The spring and summer growth of the rye was dry and bleached and valueless for grazing. New shoots were barely emerging from the fallen rye seed.

Lamb Weights and Gains Following Spring Grazing

On May 18 differences in gains made between groups of lambs were substantial and were largely attributable to the forages. The lambs on rye gained better than 3-1/2 pounds over those on crested wheatgrass and nearly 7-1/2 pounds more than those on the alfalfa hay and barley ration (table 1).

At the close of the summer grazing season, however, the gains made by the lambs that had been on rye and crested wheatgrass were nearly the same; but lambs on the two pasture treatments showed approximately a 6-pound gain over those that had been on alfalfa and barley. Because of the wide variation between lamb weights within groups on October 11 it is not possible to say whether this is a real difference or one that results from natural variability. With another year's data it will likely be possible to determine whether lambs on the pasture treatments for a month in the spring produce such an indicated gain in the fall over lambs fed alfalfa hay and barley.

Mother Ewe Weights and Gains Following Spring Grazing

During the period of the tests the mother ewes on the crested wheatgrass and rye show gains of 8 and 9 pounds respectively over those on the alfalfa and barley. The small difference between the ewes on crested wheatgrass and rye is probably largely attributable to natural differences. That the ewe gains on crested wheatgrass and rye at the close of the tests should be so similar whereas the gains of the rye lambs over those on crested

Table 1. Average weights and gains in pounds of lambs and mother ewes on crested wheatgrass pasture, on rye pasture, and on alfalfa hay and barley from April 23 to May 18.

Date	Crested wheatgrass pasture	Rye pasture	Alfalfa hay & barley
Lamb Weights and Gains			
Wt. April 23, start of tests	16.60	16.36	15.80
Wt. May 18, close of tests	29.20	32.73	24.70
Gain April 23 to May 18	12.60	16.37	8.90
Wt. Oct. 11, close of summer grazing	76.00	76.09	69.20
Gain April 23 to Oct 11	59.40	59.73	53.40
Mother Ewe Weights and Gains			
Wt. April 23, start of tests	96.40	97.36	99.09
Wt. May 18, close of tests	108.50	110.45	103.18
Gain April 23 to May 18	12.10	13.09	4.09
Wt. Oct. 11, close of summer grazing	133.30	131.64	132.54
Gain April 23 to Oct. 11	36.90	34.28	33.45

wheatgrass should be so pronounced appears peculiar. The marked difference, however, in the lamb gains between pastures probably reflects greater milk-producing qualities of the rye. During the grazing trials the rye herbage was considerably more succulent than that of the crested wheatgrass. In another year with changed weather conditions it is possible that the reverse may be true or that gains may be very similar.

At the end of the summer grazing season the ewes show very similar gains for all three treatments. This demonstrates that the mature ewes can overcome spring weight deficiencies to a large extent during the summer grazing season on the national forests.

Fall Grazing on Crested Wheatgrass

During the 11-day fall grazing period in the wheatgrass pastures the ewes gained an average of 5 pounds per head; the lambs gained an average of 4 pounds per head; and the buck lost 1 pound. These gains were made despite the fact that the sheep were in fair shape when they started to graze the crested wheatgrass.

In the Intermountain region sheep operators frequently experience a crucial need for forage in the fall as well as in the spring. Because of the quick response crested wheatgrass makes to cool temperatures and moisture, where fall storms do occur it furnishes good fall pasturage. Rye can seldom be relied on to furnish fall grazing for sheep. Consequently, crested wheatgrass is preferable to rye where fall as well as spring forage is demanded.

Grazing Capacity of the Crested Wheatgrass and Rye

For the grazing seasons in 1943 (fall and spring) approximately 169 sheep days grazing per acre were taken off the rye and 145 sheep days per acre off the crested wheatgrass. This is equivalent to 5.6 sheep months per acre for the rye and 4.8 for the crested wheatgrass. Slightly less than one sheep month per acre was thus gained off the rye over the crested wheatgrass. The crested wheatgrass, however, was a young stand being grazed for the first year, whereas the rye, being an annual was probably producing to near capacity. As the crested wheatgrass stand gets older the number of sheep it will carry per acre will likely increase. All the use was gained off the rye in the spring whereas 70 percent of the use was taken off the crested wheatgrass in the spring and 30 percent in the fall.

Cost per Sheep Month to Graze Rye and Crested Wheatgrass

It cost $2.64 and $2.98 per acre to bring the rye and crested wheatgrass respectively into production. This includes initial seeding costs and taxes. On the basis of the 1943 experience it will require a further annual outlay of 50 cents per acre to keep the rye productive and 6 cents per acre for taxes, or a total of 56 cents per acre. There should

be no expense to keep the crested wheatgrass productive, but there will be an annual outlay of 6 cents per acre for taxes. Thus, there is a current annual cost of 10 cents per sheep month for the rye and 1-1/4 cents for the crested wheatgrass.

Let us assume that the 1943 sheep months from the pastures are representative for a long-time period and that the accumulated sheep months up to and including any one year must refund the initial costs plus current charges to keep the pastures productive; or for example the total sheep months use for the first 5 years defrays the initial costs plus the current year's costs, and so on for succeeding years. Table 2 shows the cost per sheep month on such a basis for the first, fifth, tenth, and twentieth years compared with feeding alfalfa at $10.00 per ton and barley at $1.00 per hundred.

Table 2. Cost to nearect cent for cumulated sheep months use to graze the mother ewes and young lambs on crested wheatgrass and rye pastures for the first, fifth, tenth, and twentieth grazing years compared with feeding alfalfa hay and barley.

Grazing years	Cost per sheep month		
	Crested wheat-grass pasture	Rye pasture	Alfalfa hay and barley
First	0.62	0.47	0.45
Fifth	0.14	0.19	0.45
Tenth	0.07	0.15	0.45
Twentieth	0.04	0.12	0.45

For the first 10 years' use it costs 7 cents per sheep month to have grazed the crested wheatgrass and 15 cents per sheep month for the use of the rye, or a difference of 8 cents per head in favor of the crested wheatgrass. Here, where 4.8 sheep months per acre are being taken off the crested wheatgrass each year, at the end of 10 years there is a saving of $3.84 per acre for the use of crested wheatgrass as compared with rye, or enough saved on every acre of crested wheatgrass to bring more than another acre of it into production.

The difference of course between the cost per sheep month for crested wheatgrass and rye is hypothetical in that it is based on only this one year's experience. On a more favorable situation, where rye would generally reseed itself, the costs per sheep month's use over a long period of time may be more nearly equal. It is doubtful, however, that over an extended period of time rye would prove less costly per sheep month than crested wheatgrass, because even under the best of conditions rye requires reseeding every 5 to 6 years. Although information from this one year's study indicates that lambs may make in spring somewhat better gains on rye than crested wheatgrass, the fall grazing that the crested wheatgrass provides probably more than equalizes such benefit. It is rather likely also that in another year with

different climatic conditions gains of lambs on the crested wheatgrass may be just as good as those made on rye. It must be borne in mind that these are observations taken from only one year's experience.

Table 2 makes clear that crested wheatgrass or rye pastures make possible a tremendous saving over feeding alfalfa or other supplements. The additional fact that better gains are made by mother ewes and lambs on spring and fall pastures shows that a stockman can ill afford to permit his depleted, but potentially productive, spring-fall ranges to continue in a state of low productiveness. This preliminary experiment demonstrates that by seeding crested wheatgrass or rye an operator can make unproductive spring-fall range an important and profitable part of his enterprise. Rye can be used to excellent advantage to provide quick pasturage, and at the same time provide enough forage so that other range planted to crested wheatgrass can be protected long enough to allow it to establish and start to produce. Rye stubble, after the rye has run out, may then be sown to crested wheatgrass.

Information on the limitations, how to treat, plant, and manage to get results on spring-fall ranges is available in booklet form to livestock operators. By addressing a card to the Intermountain Forest and Range Experiment Station, Ogden, Utah and briefly describing the area in question and making a request, one or more of the following guides, which outline suitable procedures for the particular situation, may be obtained without charge.

1. Increasing Livestock Production and Profits by Developing Good Spring Range.
2. How to Reseed Utah Range Lands.
3. How to Reseed Nevada Range Lands.
4. How to Reseed Idaho Range Lands.
5. Sagebrush Burning, Good and Bad.

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Research Paper No. 12 April 1945

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INDICATORS OF DOWNWARD TREND ON SAGEBRUSH-PERENNIAL GRASS RANGES GRAZED BY SHEEP IN THE SPRING AND FALL

By Joseph F. Pechanec, Forest Ecologist

Indicators of downward trend in range condition are critically needed in the sound administration of range lands. An opportunity to observe and record a few of these indicators, and the sequence in which they become apparent, was afforded by a grazing study at the U. S. Sheep Experiment Station, Dubois, Idaho. In this study four pastures were overstocked with sheep approximately 25 to 30 percent. These pastures, at the beginning of the study, were good or excellent class spring-fall range having an abundance of perennial weeds and finer grasses. Topography was level to gently rolling. Grazing was typically spring and fall, with the same amount of use being made in either season.

The first signs of downward trend became evident within 3 years after the pastures were first overstocked. Listed in the order of occurrence, the indicators noted on these pastures were as follows:

1. Decrease in vigor of palatable perennial weeds and finer grasses. Tailcup lupine, arrowleaf balsamroot, royal penstemon, tapertip hawksbeard, other palatable perennial weeds and such finer grasses as bluegrasses, junegrass, and threadleaf sedge were the first to show evidence of too heavy use. Shorter stems, smaller leaves, fewer flowerstalks, and smaller flowers than on adjacent less heavily grazed ranges were the early signs. Differences in color of foliage were not evident at this stage.

2. An increase in number and size of annuals such as plumeweed (bushy birdbeak), stickseed, cheatgrass, pepperweed, and woolly Indianwheat was apparent with the first signs of decreased vigor of perennial weeds and finer bunchgrasses. Since the abundance of annuals in any one year is so much influenced by abundance and distribution of precipitation it is necessary to make comparison with less heavily grazed ranges to detect the first changes attributable to downward trend.

3. Decrease in vigor of the more robust perennial bunchgrasses, such as bluebunch wheatgrass and Indian ricegrass, as indicated by shorter leaves and fewer flowerstalks followed the decrease in vigor of palatable perennial weeds. As in the case of perennial weeds, the abundance of flowerstalks and seed was a usable indicator only when more lightly used ranges were available for comparison. In many years flowerstalks are normally absent on spring-fall ranges that are being maintained or are on an upward trend.

4. Numerous young sagebrush plants became established in the openings between mature sagebrush bushes. In other locations or in other years these young plants may or may not become established soon after the range begins to go downward. In this case at the Sheep Station the first year of the experiment happened to be a good year for the production of sagebrush seed and the second year a favorable one for germination and survival of young plants. Consequently, the young plants became established rather early. In general several seasons are likely to elapse before numerous young plants become established. A few young sagebrush plants, less than 1 per 100 square feet, are normal on most sagebrush-perennial grass ranges and should not be regarded as indicative of downward trend.

5. Death of portions of perennial weed and bunchgrass clumps. Parts of tailcup lupine and royal penstemon clumps died and bunches of ricegrass and bluebunch wheatgrass split up as overgrazing was continued. Entire plants of such perennial weeds as balsamroot and tapertip hawksbeard and smaller plants of the bunchgrasses also died out.

6. Excessive pedestaling of bunchgrasses on slopes or on less favorable sites, such as shallow rocky outcrops or south and southwest exposures next became apparent. The rapidity with which this indicator becomes apparent in other places depends upon how subject the site is to wind and water erosion. If soils are readily erosible. or slopes steep, pedestaling may become apparent earlier than on less readily eroded soils.

The foregoing indicators apply primarily to good or excellent sagebrush-grass ranges. On poorer ranges the palatable perennial weeds are likely to have disappeared. Consequently, indicators of downward trend for those poorer ranges will hinge largely on condition of the bunchgrasses and not include those revolving around growth and reproduction of the desirable perennial weeds.

These indicators on steep sloping lands and less stable soils, where chances for erosion are great, should be supplemented by indicators of lack of soil stability (see Ellison and Croft, Research Paper No. 6).

Weights of ewes and lambs kept on these pastures have so far failed to show that the range is being overstocked even though downward trend is clearly visible from the vegetation. In the fourth year of the study ewes and lambs in the overgrazed pastures were still gaining as much as those in more lightly stocked pastures. How long it will be before the sheep clearly show less gains than those in more lightly grazed pastures can be determined only by continuing the experiments. This lag in response does indicate, however, the danger of basing judgment of condition of spring range on sheep weights. It shows clearly that spring-fall range may begin deterioration several years before sheep weights start to drop.

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U. S. Department of Agriculture
Forest Service, Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 13 July 1946

HINTS FOR USE OF THE WHEATLAND-TYPE PLOWS FOR BRUSH ERADICATION IN CONNECTION WITH RANGE RESEEDING

By Jos. H. Robertson and A. Perry Plummer,
Forest Ecologists.

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The wheatland plow is doubtless our best all around implement for brush eradication despite the fact that no manufacturer has designed one specifically for work in sagebrush. This accounts for much of our trouble. There are differences between wheatland plows but probably the differences between crews operating them are more important. Much of the trouble stems from lack of experience. We believe that training and use of the following suggestions, which are merely the combined experiences of many crews, will improve our results until real sagebrush plows are made. We hope that much of the information contained in this paper will also be helpful in designing such a plow.

The following suggestions are based in part on the experience of the authors on several administrative reseeding projects of the Forest Service and Grazing Service--and they are meant to apply to similar projects whether on public or private lands. The recommendations are based also on information obtained orally or in writing from implement dealers and manufacturers, farm contractors, publications on agricultural engineering, and foremen of crews who have had experience in wheatland-plowing sagebrush. We have attempted to digest and summarize information on the operation of 18 different plows of four makes.

Recommendations

When the purchase of a plow is being considered, it is natural to ask "Which is best for brush?" It is not the purpose of this paper to answer this question. Opinion is divided, although on some features certain makes appear to excel others. This is brought out in table 1. Each "+" sign indicates that an operator has reported the plow as strong in that feature while the "-" sign is used to indicate a reported weak feature. Features that cause trouble have doubtless attracted more attention than those that are trouble-free. Hence, where no sign is given it seems safe to assume that the feature is satisfactory. Most of those who reported on weak and strong points of plows had not used more than one make under comparable conditions.

Because of differences in working conditions and in crews and also because of too limited sampling, the data of table 1 do not show which make of plow is best. The data do suggest that certain features need strengthening in all plows.

The list of features considered in table I will be followed as an outline in making suggestions for more efficient operation. Most of these features are also shown in figure 1.

Effectiveness of brush eradication depends on proper setting and adjustment of the plow even more than on size of brush or condition of the ground. Experience has shown that the plow should be set at an angle of 40° to 45°. This is the setting recommended for hard ground or shallow plowing of farm land; the setting that gives the minimum width of cut and at the same time the best kill of brush. The principle is illustrated if we drag a pencil across a table by a string attached to the right of center.

The adjustment is made by moving the line of pull to the right and setting the land wheel to run straight ahead. When the drawbar adjustments are right, the rear end will not swing away from the furrow. The line of pull should also be horizontal so that there is no tendency to raise either the front or back of the plow. The plow should be set level to make all disks cut the same depth, which need not be over 2 inches. As in hand grubbing, sagebrush is found to yield easiest when it is hit 1 to 2 inches below the ground.

Cutting into hard ground is really the job of a disk plow which has disks with greater concavity for penetration. However, use of a full set of wheel weights on each furrow wheel, setting at the minimum angle and mounting a seeder box or other weights on the frame will help in this respect. Except for presence of rocks it would be feasible to get more concave, thinner disks and sharpen them occasionally. Smaller disks, 20 to 24 inches, will cut into hard ground better than the commonly used 26-inch size but they will also clog oftener and wear out bearings faster. They are not recommended for general use in sagebrush.

Adjustment levers sometimes fail to give sufficient clearance when the plow is being walked, or to give the precise depth setting for shallow covering of broadcast seed. Ordinarily in plowing, the rachet collars at the tops of the axles should be set in the lower holes. It is sometimes necessary to move these to the upper hole. For example, a seeder platform built on the rear of the tractor may foul the lever set for shallow plowing. The upper hole should be used when the plow is to be walked over obstacles. The adjustment is easily made.

The mistake is often made of setting the depth adjustment to plow 4 to 8 inches in striving for better brush kill or greater penetration of hard spots. Since the disks must roll over some of the brush, the deep setting merely adds to draft, loosens the seedbed too much, and covers seed too deep on softer ground. It is better to set the plow at 2 to 3 inches, using what weights are necessary to hold it at that depth on hard ground.

Draft of this kind of plow, when properly set, is 15 to 20 pounds per inch penetration per disk in moist, loose ground. This is increased as much as 50 percent in sod and 100 percent in hard, dry ground. The effect of sagebrush on draft is unknown but evidently is less than that of sod. The

Table I. Wheatland-type plows. Summary of strong and weak points on 18 plows of four makes.

Make of Plow	A	B	C	D
No. of plows evaluated	9	4	3	2
Features Considered:				
Effectiveness of brush eradication	- +++++	++	+	
Cutting into hard ground	---	+	-	+
Adjustability	+	-		
Draft	+++	+	-	
Hitch				
Strength	-		+	-
Design	---	--	-	+
Disk Gang				
Disks	- +++	+++	++	- +
Arbor Shaft	------ ++	--- +	-	
Frame				
Strength	--- +++	- +	- ++	+
Clearance	-- +++	-	+	+
Bolts	---- +++	++	- +	-
Castings	--- +	-		-
Bearings	------	--	-	
Steering rods	----		- +	-
Power Lift	-	-		
Wheel axle	---			
Seeder attachment	++			
Position	---			
Feeds	+			
Drive chain	-			
Land measure	+			

This summary was compiled from our own observations and from information furnished by these personnel: Grazing Service--T. J. Snyder, E. H. Holman, G. F. Trescartes, W. M. Parsons; Forest Service--J. Gardner, R. Hollock, H. Sweetwood, L. Heywood, G. Allred, O. Torgerson, R. H. Park; Soil Conseva-tion Service--J. Taylor.

secret of getting light draft in plowing brush is in having the three plow wheels aligned parallel with the tractor tracks. If the land wheel slips or runs toward the center, the line of pull of the hitch is too far left on the frame. A center hitch on the tractor is desirable. Also plowing as shallow as consistent with a good brush kill and proper seed covering will lighten the draft.

The hitch in some instances gives trouble as a result of using a crawler tractor with a plow hitch designed for wheel tractors. Most of such hitches are soon broken in turning because they are a foot or so too short. A properly designed hitch, if found to be too weak, can be strengthened by welding angle iron to it, preferably after the proper hitch adjustment has been found by trial. One operator suggests extending the tractor drawbar when the plow hitch is too short. It is unwise to use a plow tongue that requires the tractor operator to pay much attention to keeping it free of the tracks. Too many other points need attention if a good job of seeding is to result.

Hitches are also broken by operators who try to back the plow to get clear of brush. These plows cannot be backed. It is better to carry a short chain or cable, unhitch, and pull the plow off the brush pile from the rear.

Two-plow hitches are available making it possible for a 60 hp. or larger crawler tractor to accomplish nearly double the work with no increase in manpower. A 2-plow outfit on level ground can plow and seed 25 acres in an 8-hour shift. Specifications for these hitches can be obtained from the U. S. Bureau of Land Management, Box 751, Reno, Nevada or by asking the International Harvester Co., 180 N. Mich. Ave., Chicago for its leaflet on the two-plow hitch CWIH-15. The make of the lead plow determines certain details in design of the hitch.

Disk gangs, though usually satisfactory, are subject to a variety of troubles when used in brush and rocks. As suggested in the table, the arbor shaft or gang bolt is generally too light. Often the tightening nut on the end of the arbor shaft comes loose, allowing a disk to break or lose off, or spacer washers to break. To prevent this, grease the tightening nut and washer then draw the nut down as tight as possible.

Breakage of disks on rocks will be reduced if alloy steel disks are used. Most makers furnish these as special equipment. Larger disks roll more freely and will clear rocks better.

Frames of wheatland plows occasionally break, and wheel axles bend, as for example, when a fast moving front wheel drops into a badger hole. As broken bolts probably cause more time loss than frames, they should be replaced with steel bolts having lock washers. Then all bolts should be inspected or tightened daily. A plow should never be taken out on a project without a good supply of spare bolts of sizes used in the frame and castings. Since trash bars appear to catch brush rather than to help keep the plow clean, they may as well be removed unless it is necessary to work wet, heavy soil.

Castings break so frequently, especially with a new plow on rocky or gullied land, that some foremen have considered it necessary to keep an acetylene welding outfit and a supply of scrap steel on the project. If more than one plow is in use far from the repair shop, it is economical to make repairs on the job. Often part or all of a casting is lost when it breaks or loses a bolt. With ingenuity and the right tools, the crew can often improvise castings and save time while a new part is being obtained.

The bearing that cuts out most often is the one in the front furrow wheel. The life of the bearings can be lengthened in most cases by using more and better grease. A plow in steady use needs greasing twice daily. A farm contractor who changed to a higher grade grease, "lubriplate," reports no more bearing trouble. The grease fittings of the wheel bearings are very hard to reach unless the wheel stops in the right position. Hence, greasing of the wheels is best done before the tractor is shut off. That care of the bearings has much to do with their life is suggested by statements from different operators. One operator finds it necessary to replace them after 1,000 acres, another after 5,000.

As a further precaution against excessive wear on the bearing and to reduce draft, the alignment of the front wheel should be set straight ahead or slightly outward. This wheel should never run outward more than one inch. The practice of crowding the land side of the furrow to increase the width of cut an inch or two may also wear the front wheel bearing excessively.

Steering rods of great strength are needed in sagebrush. Round iron rods have been successfully reinforced by welding angle iron the full length to prevent bending. An iron pipe might be slipped over the rod if more convenient than welding. Also care should be taken to avoid right turns as they cause most of the steering rod trouble.

The power lift occasionally fails through wear or being jammed by brush. Proper tension on the assister spring is important. A more frequent trouble results from the brush catching and breaking the trip rope or tripping the lift. The trip lever is sometimes bent by brush. The only remedy, short of new design, may be to weld an extension on the trip lever to hold the trip rope above the brush. By proper use of a good lift, an operator who is alert with the trip rope can often prevent the plow from becoming clogged with brush.

Seeder attachments have proved very much worthwhile for broadcasting while plowing. In all instances that we know of the seeder has been used as a broadcast sower by removing the boots and seed delivery tubes. Most crews have let the seed scatter from the seed cups to mix with the soil as it is turned. Others have made galvanized iron troughs for each seed cup to drop the seed in the wake of the disks. One crew reversed and reset the box. Any method that mixes most of the seed with the top inch of soil will be satisfactory. The land measure feature makes it easy to adjust the rate of seeding. Fluted feeds with gate adjustments are most trouble-free for light grass seeds.

Seeder drive chains that are not protected or protected only by a light shield are subject to breakage by brush. A heavy shield should be made strong enough to crowd brush aside without bending.

The operator's first step should be to obtain and study the maker's guide on its assembling, care, and operation of the plow. It is important to do this while looking at the plow. It is well also to obtain the parts list and keep it with this plow.

Following the manufacturer's guide insofar as it applies to sagebrush eradication is essential to get the best results.

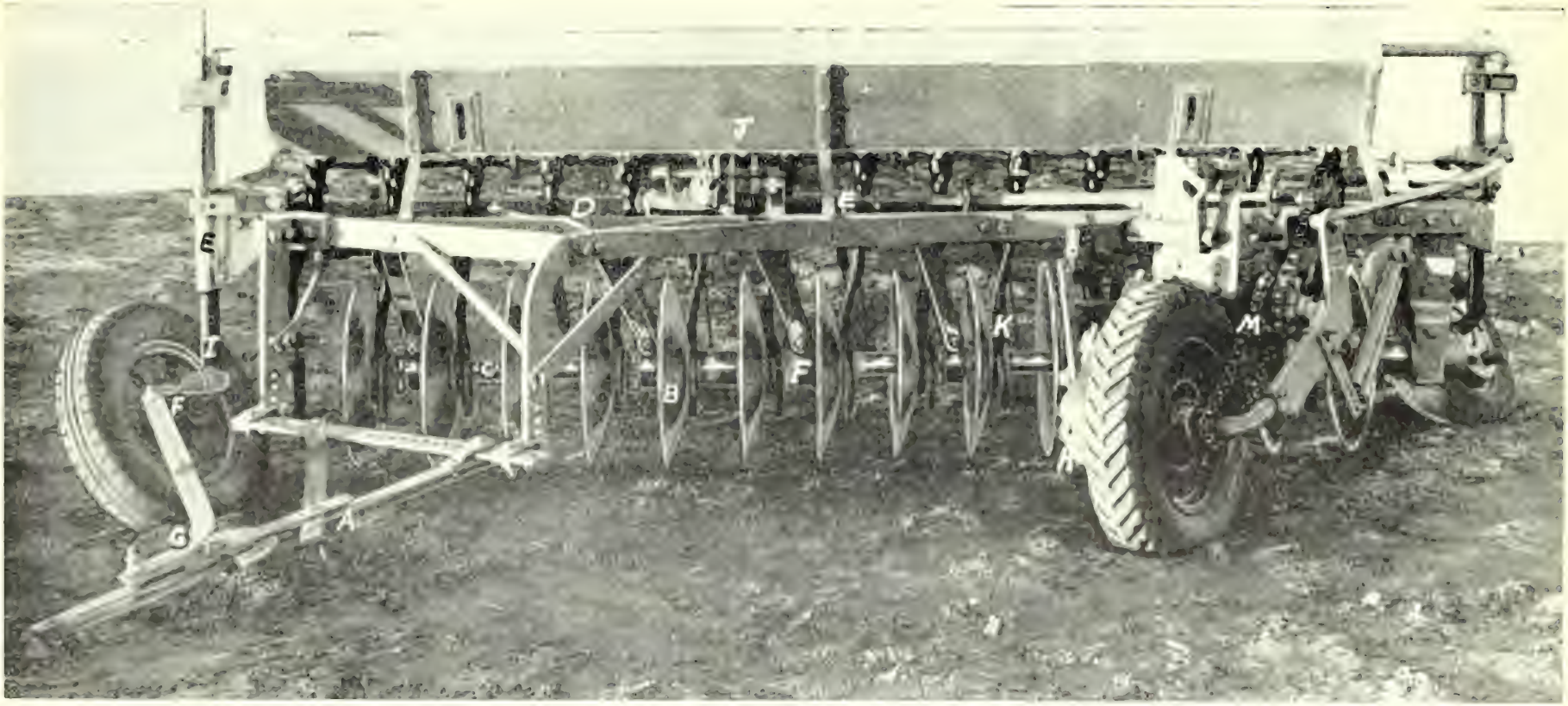

Figure 1. A wheatland or oneway plow labeled to show features evaluated in table 1. Design and photograph by the National Farm Machinery Cooperative.

A. Hitch
B. Disk
C. Arbor shaft
D. Frame
E. Casting
F. Bearing
G. Steering rod
H. Power lift
I. Wheel axle
J. Seeder box
K. Seed delivery tube
L. Feed
M. Seeder drive chain

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U. S. Department of Agriculture
Forest Service, Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 14 July 1947

SEASON, DATE, AND DEPTH OF PLANTING CRESTED WHEATGRASS AND OTHER GRASSES AT LOWER ELEVATIONS IN NORTHERN NEVADA

By Joseph H. Robertson, Forest Ecologist

SUMMARY

Fall seeding after October 15 can be expected to give better results than can seeding before that date at lower elevations for which adapted grasses are available, but where early fall precipitation is erratic. Under such conditions and where snow cover is intermittent, early spring planting in northern Nevada is likely to be as good as any fall planting. Early fall and late spring plantings are unreliable because seed deteriorates in the ground under conditions of wetting and drying that are unfavorable for rapid seedling emergence and establishment.

Seedling emergence is influenced by small variations in depth of planting. Crested wheatgrass, and probably most mixtures containing it as a base, should be planted one-half inch deep if the soil is a loam. Certain other investigators have suggested that lighter soils require deeper planting. The 1-inch depth is better for tall oatgrass while bluebunch wheatgrass does equally well at one-half and 1 inch.

To obtain good stands from plantings made at other dates or depths than optimum, the seeding rate must be increased. These conclusions have grown out of studies conducted at elevations of 4,400 to 5,200 feet in northern Nevada since 1939.

The Problem

Experience in the Intermountain region has shown that success in range reseeding usually depends on soil moisture which in turn is closely related to elevation. On ascending any of the mountain ranges of the region until moderate elevations are passed, an increasing number of species is found to be adapted to artificial reseeding and their establishment is easier than at lower levels. There seems also to be more latitude as to season of planting until temperature alters this rule at high elevations.

Because fewer species proved adapted and establishment was so difficult at lower elevations, more detailed studies were begun in 1939 to learn the best date and depth for seeding. Continued low success from fall plantings led to inclusion of spring dates in the studies in 1942. Elevations from 5,200 feet on the foothills of the Santa Rosa Mountains down to 4,400 feet in Paradise Valley, Nevada, all in the big sagebrush type, were included at that time.

Inasmuch as this part of Nevada receives little or no effective summer rainfall, conditions for survival of grass seedlings are most critical toward the end of the summer. For this reason only June-August precipitation for the period 1940 to 1945 is tabulated here.

Table 1. Summer precipitation during the years of this study at two stations 5 miles apart.

Station	Elevation	Inches of precipitation					
		Normal	1940	1941	1942	1943	1944	1945
Santa Rosa Substation	5,200	-	1.97	5.53	.95	1.80	2.29	2.45
Paradise Valley Ranger Station	4,650	1.71	.80	2.55	.41	1.49	2.02	3.09

From these data we see that the 550-foot increase in elevation was associated with a 44 percent higher rainfall, or .25 inch more per month during the summer. It is well to note that half of the summers were drier than normal.

The Studies

Beginning in 1939, 100 live seeds of three species were planted in duplicate randomized rows at two depths each 2 weeks from mid-September to mid-November for 4 years. Rows were spaced at 12 inches. This is equivalent, in the case of crested wheatgrass, to 2 pounds per acre.

Table 2. Responses of three grasses to the fall tests.

	Crested wheatgrass	Bluebunch wheatgrass	Tall oatgrass
Av. seedlings in percent of seed	18	7	8
Av. established plants in % of seed 1/	9	5	2
Av. survival plants in % of seedlings 2/	53	52	58
Total emergence from best date 3/	370	231	212
Total survival from best date	232	164	145
Total emergence from worst date	202	115	62
Total survival from worst date	102	40	33
Better fall planting depth 4/	1/2"	1/2"-1"	1"
Total emergence from better depth	846	446	322
Total survival from better depth	473	227	218
Total emergence from worst depth	588	300	320
Total survival from worst depth	271	169	151

1/ Plants surviving 2 years were considered established.
2/ Decimals of first three rows rounded off after computation.
3/ Planting was at intervals of 2 weeks, Sept. 15 to Nov. 15. Nov. 15 was the best, Sept. 30 the least favorable average seeding date for all species.
4/ Two mechanically controlled depths were tested, 1/2" and 1".

The data indicate that 2.3 times as much seed was needed on the worst date to give as many 2-year-old crested wheatgrass plants as obtained from planting on the best date. The worst depth required 75 percent more crested wheatgrass seed for a total survival equal to the best depth. Only one-fourth as much seed is needed when seeding is done on the best date and depth combined as for the poorest date and depth tested. The importance of this relationship is seen when it is considered in terms of cost and stand.

Indications by 1941 were that the better stands were from late fall seeding so a study was initiated to compare the October 30 and November 15 planting dates with two early spring dates. The data for this part of the study are in table 3. The earliest planting was made as soon as the ground was bare of snow and slightly dry at the surface, the second being 2 weeks later. These two dates were about April 1 and April 15 of 1942 and 1943. This study was otherwise similar to that summarized in table 2 but ran only two planting years, the summers of which were drier than average as shown in table 1.

Table 3. Results of two comparable spring and fall plantings of 32 8-foot rows.

	Crested wheatgrass	Bluebunch wheatgrass	Tall oatgrass
Total viable seeds sown	3,200	3,200	3,200
Total seedlings emerged	865	728	648
Av. seedlings in percent of seed	27	23	20
Total established plants after 2 years	536	475	277
Av. established plants in % of seed	17	15	9
Av. established plants in % of seedlings	62	65	43
Total emergence from spring plantings	471	506	465
Total survival from spring plantings	258	331	169
Total emergence from fall plantings	394	222	183
Total survival from fall plantings	278	144	108

Survival from mid-April plantings was 89 percent of that from those of April 1. Results have been poor from miscellaneous plantings made after April 15 in this area.

But what becomes of seed planted at the wrong time? In seeking the answer to this question, two dozen 2"x2" cheesecloth sacks containing 100 seeds each were buried one-half inch deep on tilled land, half in May, and half in July. They were dug up, examined, and germinated in July, August, September, and October. Average mortality of crested wheatgrass was 43 percent; of bluebunch wheatgrass seed 49 percent. Interrupted germination when the surface dried too quickly after storms appeared to be the cause of most mortality. Once their germination was halted, seeds always refused to resume growth in the laboratory. High soil temperature was not an evident factor since no deterioration of seed was found in dry soil.

Following the leads from the studies reported above, tests of late fall and early spring plantings were extended until 78 comparisons were available for an aggregate of 40 species. Each comparison is based on paired plots planted by the same method to the same lot and amount of seed late in the fall and early in the next spring. These results are presented in table 4.

Table 4. Average numbers of plants per 100 feet of row as counted in 1945.

	Date of planting							
	1942	1943	1943	1944	1944	1945	All years	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Grasses	38	32	43	60	72	100	51	64
Weeds and browse	22	15	37	55	-	-	29	35
Crested wheatgrass	25	90	82	95	62	65	56	83
Intermediate "	-	-	130	175	110	112	120	143
Bluebunch "	12	57	43	66	42	40	32	54
Bluestem "	-	-	20	40	30	31	25	35

These results continue to indicate that spring planting before April 15 in northern Nevada and climatically similar areas can be expected to give stands equal to or better than those obtained from fall plantings.

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SEEDING SOUTHERN IDAHO RANGE LANDS BY AIRPLANE 1/

By A. C. Hull, Jr., and George Stewart
Range Conservationists

Airplanes have frequently been used in southern Idaho to dust crops, spread bait for crickets, spread fertilizer, hunt coyotes, and to scatter grass and clover seed. The grass and clover seedings have been made at different locations, by different planes, and by different individuals and agencies. They were not a part of a large-scale research program; nor were they designed for direct comparison with one another in terms of cost or in terms of methods of seed distribution.

The seedings reported on in the following pages vary from a relatively crude broadcast from an airplane cockpit made near American Falls in 1938 to the highly specialized pellet seeding near Gooding in 1947. The others were done at Ola in 1939, at Gooding, Caldwell, and Preston in 1943, and at Cow Creek near the South Fork of the Boise River in 1945. These do not form a complete listing of airplane seedings in southern Idaho; they are simply the ones on which data are available. From them, the authors have attempted to provide useful information, by pointing ou the methods of seed distribution and discussing some of the features tha the various trials have in common.

The seven seedings are described below in order of the time at which t were done. Following these separate descriptions, there is a short s description, a discussion of factors affecting the cost of airplane seeding, and a discussion of factors affecting seed distribution.

Strip Seeding Near American Falls, 1938

In the fall of 1938, a 320-acre area northwest of American Falls wa broadcast seeded in strips by flying over it 8 times and emptying b a 40-pound sack of crested wheatgrass (Agropyron cristatum) seed f the cockpit of the plane on each trip. Seed fell in a 100-foot sw

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1/ The writers are indebted to the Bureau of Land Management, t Conservation Service, the personnel of the Boise National F to numerous private individuals for information regarding a seeding which the various agencies or individuals supervis which they cooperated.

on each trip and left 230 feet unseeded between swaths. The seeded area supported a thin stand of sagebrush (Artemisia tridentata and A. tripartita) with an understory of cheatgrass (Bromus tectorum) and Sandberg bluegrass (Poa secunda). Six years after seeding there was an average of approximately one plant per 50 square feet on the seeded area in a very patchy distribution. The landowner reports that new plants have started from seed produced by the original plants and that plants have increased in numbers four times since seeding in 1938. If this is the case, there would have been one plant to 200 square feet after seeding, which would mean that about one seed from every 1,000 broadcast developed into a plant. The crested wheatgrass plants are now producing approximatel 50 pounds of air-dry herbage per acre. Stands of crested wheatgrass on similar land not far distant that were drilled on prepared seedbeds produced over 1,000 pounds of herbage and 200 pounds of seed per acre during the third and fourth growing seasons.

Cross Seeding Near Ola, 1939

A 1,200-acre area near Ola was broadcast seeded by airplane in the fall of 1939. Seed distribution cost 50 cents an acre, exclusive of seed. Seed was broadcast at the rate of 5 pounds per acre with 4 pounds of bulbous bluegrass (Poa bulbosa) and some crested wheatgrass and white sweetclover (Melilotus alba). Flying strips were 50 feet apart and control was by flagmen on the ground. The area was seeded twice with the second flight at right angles to the first. Greased cards on the ground caught the seed on sample plots and showed good distribution. The seeded area was mostly cheatgrass-covered foothill land with some brush and conifers. The bulbous bluegrass established itself very slowly but by 1944 there was a good stand of this grass over most of the 1,200 acres. It now furnishes excellent early grazing and is spreading to adjacent areas. One reason for the success of this seeding is that the small, eavy bulbils of bulbous bluegrass (which are used as seed) work through tter to the soil and do not need any soil covering. On this area are casional plants of crested wheatgrass, mostly in brush and places where y were covered by natural means.

Strip Seeding of Sagebrush Land Near Gooding, 1943

he fall of 1943, a 400-acre area of burned and unburned sagebrush n of Gooding was broadcast seeded in strips to crested wheatgrass and us bluegrass by airplane at the rate of 12 pounds an acre. Strips spaced 66 feet apart and ground control was by flagmen. A Venturi unnel was used for seed distribution. The plane flew approximately t above the ground and most of the seed fell in a 5- to 20-foot eaving wide unseeded strips between swaths. The first growing there was a poor to good stand of seedlings of both species on ed strips on both the unburned and the burned areas. The good seedlings can be attributed to the heavy precipitation during spring of 1944 which allowed seed on the surface to germinate small plants. Few of the crested wheatgrass plants and only

part of the bulbous bluegrass plants survived the severe summer drought of 1944. In 1947 the bulbous bluegrass had a somewhat patchy stand with practically no crested wheatgrass.

Strip Seeding North of Caldwell, 1943

A total of 450 acres 20 miles north of Caldwell was strip seeded by airplane in less than 3 hours in the fall of 1943. Seeding was at the rate of 8 pounds per acre with one part of bulbous bluegrass to two parts of crested wheatgrass. The plane flew at a height of approximately 20 feet. Strips were spaced 66 feet apart and were controlled by flagmen. A Venturi windtunnel was used to scatter the seed but distribution was very poor. Seed fall averaged 6 feet to the windward and 28 feet to the leeward of the plane, leaving half of the area with no seed at all. More than 50 percent of the seed fell within the middle 10 feet of the 34-foot seeded swath. Because it was necessary to pay only the plane expenses and personnel, this seeding cost 11 cents an acre, exclusive of seed. However, as only half the area was covered with seed this cost would be doubled for full coverage. Before seeding, the area had a fairly open stand of tall sagebrush which averaged 5 plants per 100 square feet. The chief understory species was Sandberg bluegrass which produced 103 pounds of air-dry herbage per acre. Other grasses yielded a total of 54 pounds per acre. After seeding, about 10 percent of the broadcast area was rolled with a 30-inch concrete-filled culvert with spiked-teeth to mash down the brush and help cover the seed. The spring of 1944 was favorable for seedling establishment. On the rolled area a little less than one grass seedling per square foot was found on the seeded part of the strip. On the unrolled area there was one plant per 10 square feet on the seeded portion. On both rolled and unrolled portions the Sandberg bluegrass was severe competition for the young wheatgrass seedlings. An examination in 1947 showed that plants were patchy in the rolled portions and had survived only in small brush piles and where seed might have been covered by soil or litter. On the unrolled parts, only an occasional plant was found in openings where seed was probably covered in a depression. On the rolled portion one seed in every 800 broadcast by plane produced a mature plant, and on the unrolled portion only one seed in 3,000. On an adjoining area that was accidentally burned in 1944 and drilled that fall to crested wheatgrass and bulbous bluegrass at 6 and 3 pounds per acre, respectively, there was one plant for every 9 seeds drilled (table 1).

Table 1. Number of reseeded plants per 100 square feet from 3 different treatments on a seeded area north of Caldwell

Species	Treatment		
	Airplane broadcast with no ground treatment	Airplane broadcast and rolled	Burned drill
	1943	1943	1944
Crested wheatgrass	0.5	5	552
Bulbous bluegrass	1	1	128
Total plants per 100 square feet	1.5	6	680

Spot Seeding at Preston, 1943

Eight hundred acres of hilly range land near Preston was spot seeded by airplane with 1,200 pounds of seed in the fall of 1943. Seeding was done from a Piper Cub which carried 80 pounds of seed per trip and flew from an alfalfa field at an average distance of 2 miles. Seeding took 2½ hours and plane rental was $40.00 or 3-1/3 cents per pound of seed. The seeded area varied from bare south exposures to thick stands of bigtooth maple (Acer grandidentatum) with some aspen (Populus tremuloides). With the small plane the pilot was able to get close to the ground and seed the desirable open and semiopen brush patches and to skip the bare south exposures. The falling leaves covered the seed on the brush areas and gave a good stand of reseeded species, which were mostly crested wheatgrass and orchardgrass (Dactylis glomerata) with some tall oatgrass (Arrhenatherum elatius), smooth brome (Bromus inermis), and timothy (Phleum pratense).

In 1947 counts were made on sample plots of the number of plants of the various species on the different site conditions and on ridgetops within the seeded area which had been drilled to the same species at 10 pounds per acre 2 years before the airplane broadcasting (table 2). At the time of drilling these ridgetops supported a sparse cover of sagebrush with an understory of annual weeds and many sagebrush seedlings. In making counts, the large bare south exposures which were undoubtedly missed in seeding were not sampled. Although there is no accurate record of the area seeded or the rate of seeding on any given area, the relative success of the species shows the adaptability of the various site conditions for airplane seeding. Best results were from drilling, and from airplane broadcasting in aspen, maple, sagebrush, and cheatgrass in the order named. North exposures produced better stands than did south exposures.

Table 2. Average number of reseeded grass plants per 100 square feet on the various sites of the airplane seeding and on a drilling near Preston

Species	Sites and vegetation before broadcasting in 1943						Ridgetops drilled in 1941
	South exposures			North exposures			
	Cheat-grass	Sage-brush	Maple	Sage-brush	Maple	Aspen	Sagebrush and annual weeds
Crested wheatgrass	0.1	0.6	3.4	1.0	3.2	2.8	64.4
Orchardgrass	0	0.1	3.2	1.2	18.6	35.6	8.7
Tall oatgrass	0	0.1	0	2.0	0.2	0	0.4
Smooth brome	0	0	0.2	0	0	3.2	0.3
Timothy	0	0	0.3	0	0.2	14.0	0
Total plants per 100 sq. ft.	0.1	0.8	7.1	4.2	22.2	55.6	73.8

Controlled Seeding of a Burned Area on the Boise River, 1945

In the summer of 1945 a 16,000-acre burn occurred on the South Fork of the Boise River. That fall it was seeded to produce forage for livestock and to prevent erosion and siltation in the Arrowrock Reservoir. Before burning, vegetation varied from thin stands of brush and cheatgrass on south-facing slopes to heavy stands of brush and aspen on north-facing slopes. After burning and before seeding, the area was classified into the four following kinds of site:

Site 1 - South and west slopes with a thin stand of sagebrush and cheatgrass before burning; poor, thin soil; no ashes left.

Site 2 - Flats and similar areas with a medium to good cover of sagebrush and other vegetation; poor to fair soil; thin ashes after burning.

Site 3 - Mostly east and north slopes with heavy stands of sagebrush and mountain brush species; good soil; fair cover of ashes.

Site 4 - Steeper north and east slopes with aspen and heavy stands of mountain brush species; excellent soil; deep ashes.

Following the above classification, about three-fifths of the 16,000 acres fell into site 2. Site 1 accounted for about one-fifth and sites 3 and 4

together for about one-fifth of the area. The entire 16,000 acres was broadcast seeded by airplane. All areas which were level enough were drilled, and sites 3 and 4 which had enough ashes to cover the seed and the creek bottoms in site 2 were hand broadcast over the airplane broadcast. The acreage sown by each of the methods, the cost per acre, and amount of seed sown are shown in table 3. Planes used for the seeding were an L-5, a Travelair, and a Ford Trimotor. Two types of Venturi wind tunnels were used and one of them was modified several times in an attempt to get maximum width and uniformity of seed distribution. Neither wind tunnel gave a uniform spread of seed over a wide swath. Several tests were made on seed distribution from various heights of flight and different wind velocities, as shown in table 4. Because of steep topography the pilot could not get close enough to the ground to make the seed fall within flagged lines. The required amount of seed was therefore broadcast into each drainage or topographic area by means of cross flying the drainage in different directions with ground checks.

During the first summer an excellent stand of grass was obtained on the drilled plots and some of the crested wheatgrass produced seed. Stands from airplane broadcasting were good only where ashes were deep enough to cover the seed and on steep slopes where soil sloughing had covered the seed. During the second growing season plant counts were made on all four sites and for all methods of seeding at several locations and estimates were made of average herbage production (table 5). Drilling gave the best results and seed covering by deep ashes was next, although it was only one-fifth to one-half as good as drilling. In many cases the abundant brush sprouts or the deep ash areas crowded out the grass seedlings. Where this did not occur stands were excellent. Broadcasting on burned areas with light or no ashes gave poor results. When crested wheatgrass and smooth brome only are considered, the difference in stands resulting from seed covering by drilling, deep ashes, and no seed covering is striking.

Pellet Seeding of a Large Burn Near Gooding, 1947

In the fall and winter of 1947 a 25,000-acre burn north of Gooding was broadcast seeded by airplane with seed enclosed in pellets. This was an experimental test seeding of pellets by airplane and because of the unique seeding method it was given much publicity. Newspaper reports and conversations with representatives of the company having the seeding contract are the basis for the data on this seeding. Seeding was at the rate of 43 pounds of pellets per acre which contained 1½ pounds of crested wheatgrass and ½ pound of yellow sweetclover (Melilotus officinalis) and a small amount of fertilizer. There were five seeds of crested wheatgrass in a 3/8-inch pellet and five seeds of yellow sweetclover in a 1/4-inch pellet. Pellets were made from soil right on the area. A landing field was constructed on the seeded area to save unnecessary flight to and from an airport. Four planes did the seeding with each plane carrying about 800 pounds of pellets per trip. Flying height was about 500 feet. Planes were guided by ground flagmen and flew over strips spaced 66 feet apart. Pellets were dropped into a Venturi wind

Table 3. Acres sown, cost, and seed mixtures for three methods of seeding on the South Fork burn

	Airplane broadcasting	Hand broadcasting 1/	Drilling
Acres sown by each method	16,200	2,200	1,000
Cost of seeding per acre (dollars)	$1.61	$1.52	$5.41
Seed sown (pounds per acre)			
Crested wheatgrass	1	3	6
Bulbous bluegrass	6	4	1
Smooth brome	1	1	1
Total	8	8	8

1/ Seeding rate for hand broadcasting is double that shown as these areas were also seeded by airplane.

NOTE: Costs are for 1945 and include: mixing, hauling, and loading seed; idle labor when weather made flying or drilling impossible; construction and mounting of seed hoppers and Venturi flumes; and maintenance of the L-5 airplane.

Table 4. Data on airplane seeding tests showing wind, height of flight, seed drift and distribution, and seeds per square foot

Location	Wind velocity m.p.h. (approx.)	Flying height (feet)	Width of swath covered (feet)	Spread to leeward[1] (feet)	Type of seed distribution in swath	Average seeds per square foot[2]
Dixie Airport	5	200	90	110	Fair	15.6
Dixie Airport	5	200	150	150	Good	13.0
Dixie Airport	10	200	310	280	Fair	7.0
Near Boise	10	200	[3]/50	[3]/125	Fair	29.5
Near Boise	10	200	[3]/50	[3]/ 75	Good	30.5
Near Boise	10	700	(4/)	(4/)	(4/)	(4/)
Boise Airport	5	500	75	71	Fair	41.2
Boise Airport	10	500	(3/)	[3]/125	1 seed	-
Near Dixie	10	500	[3]/400	[3]/400	Good	4.6
Near Dixie	15	[5]/500	[5]/1900	[5]/1500	Fair	7.5
Caldwell	15	20	34	28	Poor	178.0

1/ In some cases all seed fell to the leeward of the line of flight so that the distance to the leeward is often greater than the total width of swath

2/ This column is not comparable to rate of seeding as many of these tests were to check rate of seeding, seed distribution, and spread at different flying heights. Figures merely show variations which were encountered.

3/ Plots not far enough to windward or leeward to catch all seed. Seed probably went further.

4/ Seed fell beyond last plots which were 125 feet to leeward.

5/ Two flights - 200 feet apart.

Table 5. Reseeded grass plants per 100 square feet from each of the four sites and from three different seeding treatments and estimated herbage production on a 1945 burn on the South Fork of the Boise River

Treatment and species	Plants per 100 square feet					Herbage production 2/ (lbs. per a.)
	Site 1 1/	Site 2 1/	Site 3 1/	Site 4 1/	Average	
Airplane broadcast						
Crested wheatgrass	2	5	7	-	5	
Bulbous bluegrass	26	50	87	-	54	
Smooth brome	0	0	0	-	0	
Total	28	55	94	-	59	50
Hand broadcast 3/						
Crested wheatgrass	-	33	60	33	42	
Bulbous bluegrass	-	83	175	82	113	
Smooth brome	-	0	1	8	3	
Total	-	116	236	123	158	300
Drilling						
Crested wheatgrass	135	268	327	420	288	
Bulbous bluegrass	233	230	190	235	222	
Smooth brome	2	10	30	70	27	
Total	370	508	547	725	537	1,200

1/ Site 1 - Thin sagebrush or cheatgrass; poor soil; no ash.

Site 2 - Fair to good sagebrush; poor to fair soil; poor ash.

Site 3 - Heavy sagebrush and fair mountain brush; good soil; fair ash.

Site 4 - Heavy mountain brush and trees; excellent soil; good ash.

2/ Estimated average production for all sites in pounds of air-dry herbage per acre of the 2-year-old stands.

3/ The hand broadcast areas were also broadcast seeded by airplane.

- Not seeded.

tunnel where they were spread by the air-blast of the propeller. There was concentration of pellets in the middle of the swath but because of overlap of the swaths, distribution was fairly uniform. The contract cost of the seeding is $1.75 per acre for the planes and the pellets, with seed and fertilizer being extra. Data on seedling growth and stand establishment from this seeding are not yet available.

SUMMARIZED DESCRIPTION

A tabulated description of seven seedings in Idaho made by means of airplanes, together with a note of forage stands obtained, is presented in table 6. The details have been given in the preceding pages.

This table reveals that, as a whole, the forage stands obtained are mostly unsatisfactory. Only the Ola seeding yielded stands that were called "good" and none were "excellent" stands. Of the 10 reports (Cow Creek is reported in four divisions) on stands, 3 are very poor, 2 poor, 3 fair, 1 good, and 1 too recent for any data.

Airplane seeding can be expected to succeed only where hand broadcasting would succeed. So far seeding in ashes has shown some promise. Seeding in open brush or aspen where falling leaves cover the seed seems to assure good stands at least in many cases. Bulbous bluegrass has given fair to good stands from broadcasting in many cases, but is a satisfactory forage for the Intermountain region only in parts of southwestern Idaho.

GENERAL CONCLUSIONS

Seed dropped from airplanes is not endowed with magic powers which will enable it to germinate on top of dry ground and produce a strong plant. In general, all seed needs to be covered to a shallow, uniform depth before successful stands of grass can be expected. Where the seedbed is such that covering can be provided by natural means (soil, deep ashes, or leaf fall) on large areas and airplanes are able to scatter seed efficiently and cheaply, they will be found useful in seeding range lands. Rapidity of seed distribution is, of course, the greatest single factor in favor of the use of airplanes.

Seeding of range lands by airplane is still in its exploratory stages, and there will undoubtedly be many improvements in methods and techniques. It is not possible at this time to provide final information as to the feasibility of airplane seeding on any given area. When an area is judged adaptable to broadcast seeding, airplane seeding should still be compared in cost and effectiveness with other methods of broadcasting. Some of the factors which should be considered are discussed in the paragraphs that follow.

Factors Affecting Cost of Airplane Seeding

Cost of seeding is one of the first considerations. Cost of airplane seeding is usually associated directly with the distance from airports and

Table 6. Tabulated description of seven airplane seedings in southern Idaho together with forage stands obtained, 1938-1947

Year	Place	Nature of site 1/	Acres	Seed used 1/	Nature of seeding	Control used	Stands obtained
1938	American Falls	Artr Brte	320	Agcr	Strip	Sight	Very poor
1939	Ola	Brte	1,200	Agcr Pobu	Complete coverage	Flags	Good
1943	Gooding	Artr; burned	400	Agcr Pobu	Narrow strips	Flags	Very poor
1943	Caldwell	Artr	450	Agcr Pobu	Narrow strips	Flags	Very poor
1943	Preston	Artr Mt.brush Brte	800	Agcr Dagl etc.	Spots	Sight	Fair
1945	(1) Cow Creek	Burned Artr Brte	3,000	Agcr Pobu Brin	Solid	Topographic units	Poor
	(2) Cow Creek	Burned Artr	10,000	Agcr Pobu Brin	Solid	Topographic units	Poor
	(3) Cow Creek	Burned Mt.brush Artr	2,000	Agcr Pobu Brin	Solid	Topographic units	Fair
	(4) Cow Creek	Burned Mt.brush & aspen	1,000	Agcr Pobu Brin	Solid	Topographic units	Fair
1947	Gooding	Artr Brte	25,000	Pellets Agcr Meof	Solid	Flags	No data as yet

1/ Symbols: Agcr, Agropyron cristatum; Artr, Artemisia tridentata; Brin, Bromus inermis; Brte, Bromus tectorum; Dagl, Dactylis glomerata; Meof, Melilotus officinales; Pobu, Poa bulbosa.

the load which the plane can carry. For example, on the South Fork seeding the Ford Trimotor which carried 3,000 pounds of seed per trip and flew 35 miles to a suitable landing field was more economical than the L-5 which averaged 7 miles from a closer, smaller field but carried only 240 pounds of seed per trip. The Piper Cub at Preston which carried only 80 pounds of seed but which could land in a field 2 miles distant, was cheaper than the larger planes carrying more seed. Because of the varied rates of seeding and the varied percentages of areas covered by seed, it is usually better to use cost per pound of seed rather than cost per acre in estimating costs of plane seeding. Costs are estimated from seed capacity of the plane, plane rental, distance from a landing field, air speed, and loading time. Planes cannot carry as heavy a load at high elevations as at low elevations. Total seeding costs for 225 acres seeded at 5 pounds per acre by airplane in Montana averaged $1.50 per acre.[2/]

Pay load is one of the factors in determining the advisability of airplane seeding. This is especially true in the case of pellet seeding. In the 1945 pellet seeding in the Southwest it was necessary to carry approximately 550 pounds of soil into the air for one pound of the extremely small seeds of Lehman lovegrass (Eragrostis lehmanni) and sand dropseed (Sporobolus cryptandrus) used in this seeding. In the 1947 seeding near Gooding only 20 pounds of soil were required for every pound of seed of crested wheatgrass and clover. Pellet seeding is still in the experimental stage and it is anticipated that there will be considerable development in this field.

Factors Affecting Seed Distribution

Weather conditions often determine the advisability of airplane seeding. Clouds, winds, or storms during the seeding season may make airplane seeding impossible. In 1946 a plane was smashed and the pilot was killed while broadcasting grass seed on a burned area during cloudy weather. Winds cause much seed drift and uneven seed distribution.

Topography influences the height of flight which in turn is a factor in seed distribution. On level areas it is possible to fly straight lines which are controlled by flagmen. In uneven topography, however, planes may clear ridges by 20 feet and be 1,000 feet above the ground in a short distance. For this reason it is difficult to fly to flagmen and it may be easier to fly rough areas by topographic units. Up and down drafts in rough areas often make it advisable for safety to fly higher above the ground than when seeding on level areas. In sowing mustard on burns in southern California foothills a flying height of 300 feet was recommende

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2/ Friedrich, C. Allan, Seeding grass by airplane on western Montana's burned-over timberlands. Northern Rocky Mountain Forest and Range Experiment Station Research note No. 52 mimeo.

3/ Guide for mustard sowing in burned watersheds of southern California, U. S. Dept. Agr. Forest Service, California Region, August 1947.

Proper seed distribution is difficult to achieve. Variations in width of spread and in drift of seeds broadcast by airplane through a Venturi wind tunnel from different heights of flight and under different wind conditions are shown in table 4 (p. 8). The higher the plane the wider the swath and the greater the seed drift. Heavy seeds are not as subject to wind drift as light seeds. Seeds also tend to be thicker near the center of the swath. The wind tunnel should therefore scatter seed as far to the outside as possible. A typical distribution of grass seed from a flight over the Dixie Airport at a height of 500 feet and a wind velocity of 5 m.p.h. is shown in table 7. Unevenness in distribution can be partially overcome by cross stripping and by overlapping. At Ola good distribution was obtained by seeding twice with half of the seed being broadcast in one direction and the other half at right angles to the first. In the Gooding pellet seeding and in seeding mustard in California the edge of the swath where seed was scattered thin was covered again by overlapping on the next trip. This overcame bunching in the middle of the swath. On the South Fork of the Boise River, where flagmen could not be used, a topographic area was set out and the required amount of seed put on the area by seeding from two to four times in different directions. Ground examination showed that this gave reasonably good seed distribution.

There is need for considerable research work on seed distribution and drift of different species from different flying heights, at varying wind velocities, and from different types of seed distributors in airplane broadcasting. Airplane seeding costs and the feasibility of this seeding method need to be more fully determined. Field tests are also needed on the practicability of enclosing seed in soil pellets both for drilling, hand broadcasting, and for airplane seeding. Where airplane seeding is going ahead without the necessary research background seed distribution should be checked from different flying heights at the beginning of each seed job and checked in the field as the job is progressing. For field checking it will be necessary to arrange a system of signals between the field checker and the pilot.

Table 7. Distribution of seeds (three species in a mixture) at given distances to windward from line of flight. (Airplane seeding at Plum Airport, 1/4)

Distance to windward from line of flight	Seeds per square foot		
	Bulbous bluegrass	Crested wheatgrass	Smooth brome
feet			
0	-	-	-
10	3	-	-
20	11	-	-
30	31	-	-
40	28	-	-
50	27	3	1
60	24	7	4
70	20	6	5
80	12	3	3
90	6	2	5
100	4	1	2
110	2	2	2
120	-	1	1
130	-	1	1
140	-	-	1
150	-	-	1

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SEASONAL PERIODS FOR PLANTING GRASSES IN THE SUBALPINE ZONE OF CENTRAL UTAH

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SEASONAL PERIODS FOR PLANTING GRASSES IN THE SUBALPINE ZONE OF CENTRAL UTAH

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Range Conservationists

Many open grasslands in the subalpine zone are in need of artificial revegetation. Originally, the native cover of broadleaved herbs and grasses held the soil securely, and insured the absorption of rainwater during torrential storms. Much of this cover was destroyed by early unregulated grazing, however; much of the bared topsoil was washed away; and summer flash floods became common. Since the regulation of grazing, plant cover has increased, especially on the better sites, erosion is less, and destructive summer floods are fewer. There are, however, many areas that are still eroding too fast, and occasionally destructive floods still occur. The quality of vegetation in many places, both from the standpoint of watershed protection and of forage yield, is unsatisfactory. On many of these subalpine lands cultural treatments, including the seeding of grasses, are the only feasible means of stabilizing the soil. On moderate slopes and level areas, where the soil mantle is fairly deep, increased forage alone justifies the costs of seeding.

To get successful plantings on high elevation range lands it is important to know the proper seasonal period in which to plant. This research paper presents such information from a 5-year intensive study of planting periods in a typical subalpine area in central Utah. Because of the general similarity of climate in many high mountain areas in the temperate zone, the information should have rather wide application.

Soil and Vegetation of the Experimental Area

The area chosen for this study is located 10,200 feet above sea level on the comparatively level and rather broad Wasatch Plateau at the head of Ephraim Canyon on an 8-percent slope facing west. The soil is a clay loam of limestone origin. Composite samples showed a pH of 6.9, a nitrogen content of 0.3 percent, and an organic matter content of 6 percent in the top 3 inches.

The native plants that originally grew on the experimental site and general vicinity had been greatly depleted and much of the soil was eroded away. Common dandelions, sweet sagebrush, and western yarrow were the primary species occupying the land prior to use for

experimental purposes. Minor constituents were American vetch, sticky geranium, slimstem cinquefoil, false carrot, and Barbey larkspur. These are all common forbs on the adjoining land.

Climate

Annual precipitation during the 34 years from 1915 to 1948 has averaged slightly more than 30 inches. Approximately one-fourth of this has come as rain in the five summer months (May 1 to September 30) and the remainder as snow in the seven winter months (October 1 to April 30). The moisture accumulated in the ground from winter snow together with occasional showers in most summers enables most perennial plants to remain green until killing frosts occur in the fall.

The length of the frost-free period, which varies greatly from year to year, averages 80 days, with the longest period on record 111 days and the shortest 54 days. For any one year the number of frost-free days may be cut in half by either a late spring or early fall. When frosts occur in the early part of the growing season, and they occasionally do, they are very damaging to seedlings. Such frosts characteristically come in years when snow melts off early.

On these high, sparsely timbered plateaus, it is not unusual for the wind to develop into gale proportions for several hours at a time. This enormous amount of air movement has a serious drying-out effect on the surface soil and unprotected young seedlings.

Grass Species Used

The six grass species used in this study were slender wheatgrass, mountain brome, smooth brome, tall oatgrass, timothy, and Kentucky bluegrass. Slender wheatgrass and mountain brome are bunchgrasses native to this region and seeds used were of local origin. Both grasses become established easily under a wide range of conditions at high elevations.

Tall oatgrass and timothy are bunchgrasses native to Europe but long used in pastures in this country. Of the two, tall oatgrass has the wider range of use and is the more aggressive spreader. Timothy, in years of short seasons at high elevations, will not mature seed whereas tall oatgrass generally does. Timothy is best suited to moist sites.

Smooth brome and Kentucky bluegrass, introduced sodgrasses and long-time popular pasture grasses in this country, have proved themselves well adapted for seeding high ranges. Smooth brome, because of its wide range of adaptability, good soil binding qualities, palatability, and ease of establishment, is at present the most widely used and recommended species. Kentucky bluegrass is not so generally recommended for forage because of its lower

production and greater difficulty encountered in getting stands. However, once established, it is persistent and controls erosion, even under very heavy grazing. Like timothy, it is best suited and most productive on moist sites.

Experimental Procedure

Fifty viable seeds of the six grasses were sown in rows 10 feet long and 22 inches apart in four replications and during six seasonal periods over the 5 years, 1941-45. Slender wheatgrass, mountain brome, smooth brome, and tall oatgrass were sown at a depth of 3/4-inch; timothy and Kentucky bluegrass were planted 1/4-inch deep.

The study was set up on a split randomized block design and had all possible combinations of the variable factors--6 species, 6 seasonal periods, and 5 years--for a total of 180 separate treatments. To make conditions as uniform as possible, competing vegetation was weeded out during the year of planting as well as in the succeeding year.

For purposes of planting, the growing period was divided into six seasonal periods, based on development of native mountain brome. Dates of planting were designated as early and late spring, early and late summer, and early and late fall. The developmental stages, seasonal periods, and variations in dates are shown in table 1.

Table 1.--Seasonal planting periods based on development of Mountain Brome

Seasonal period	Stage of development	1941	1942	1943	1944	1945	Date variation	Av. date
Early spring	Snow off, growth starting	6-27	6-16	5-28	6-29	6-23	5-28 to 6-29	6-19
Late spring	Leaves 6 to 8 inches high; flower stalks evident	7-15	7-2	6-30	7-19	7-9	6-30 to 7-19	7-9
Early summer	Flower heads showing	7-28	7-24	7-24	8-2	7-27	7-24 to 8-2	7-27
Late summer	Seed in soft dough	8-19	8-17	8-20	8-22	8-21	8-17 to 8-22	8-20
Early fall	Seed ripe	9-6	9-2	9-1	9-11	9-12	9-1 to 9-12	9-6
Late fall	Seed disseminated	1/	9-27	10-1	10-5	11-6	9-27 to 11-6	10-6

1/ Late fall planting not possible in 1941.

It is to be noted in table 1 that there was more than a month's variation in planting dates in the early spring period during the 5 years. This was because of the wide variation between yearly dates when snow melted off and the ground had dried out enough so that plantings could be made. Similarly, it is to be observed that there is over a month's spread in late fall planting dates. In 1941, early snow falling on September 22 did not melt off, consequently the late fall planting could not be made. In 1945 the late fall planting was delayed until November 6 because of stormy weather. In this seasonal period there were very few days in which plantings could be made. Dates of planting in early summer, late summer, and early fall were within short periods of each other for the 5 years.

Development of mountain brome, as well as of the other native species, is very similar in all years at the later seasons, regardless of how late the ground is covered with snow in the spring. In years of late snow cover, the growing conditions are more favorable at the time growth starts. As a consequence, plants develop faster and make up the deficiency resulting from a later start. Late fall in the higher mountains has been judged to be any date after September 25 when plantings can be made. Generally after that date temperatures are cold enough to insure little danger of seeds germinating and succumbing to winterkilling action.

Rates of Seeding

Fifty live seeds, sown in each 10-foot row, amounted to 2.72 seeds per square foot, or 5.0 seeds per linear foot. Each year the germination of each seed lot was determined and enough seeds were counted out to equal 50 good seeds. The seeding rate in pounds per acre is shown in table 2. Because of the small size of timothy and Kentucky bluegrass seeds, the seeding rates in pounds per acre were lower than for the larger seeded species.

Table 2.--Number of seeds per pound and seeding rates for six grasses

Grass species	Number of seeds per pound	Seeding rate
		Lbs. per acre
Slender wheatgrass	153,840	0.77
Mountain brome	40,000	2.98
Smooth brome	118,000	1.01
Tall oatgrass	122,000	0.98
Timothy	1,140,000	0.10
Kentucky bluegrass	2,320,000	0.05

Observations Taken

Observations were of two kinds, seedling counts and relative plot ratings. Both were made in the late summer of the year following planting. By that time the heavy mortality was over and performance of each species could be judged.

Relative plot ratings consisted of an evaluation of the stand on a standard scale from 0 to 10. A rating of 1 was very poor and 10 was very good or as much as could be expected. Factors considered in making ratings were distribution in the row and number of plants. These factors were helpful in determining the probable future stands.

Results

Percentages of plant survival are shown in table 3 and relative plot ratings in table 4. Slender wheatgrass, mountain brome, and smooth brome gave very comparable results. Slender wheatgrass proved to be the most consistent in establishment for all seasons. Analysis showed that there was no significant difference between seasons for this species. Explanation for this is that the seedlings of this native strain were much more resistant to freezing and thawing than those of the other species. Mountain brome and smooth brome were second and third best, respectively, in percentage establishment. However, statistical analysis of plant survival showed there was no significant difference in establishment between these two species and slender wheatgrass. There was a highly significant difference between establishment in different seasonal periods for the bromes. This is, of course, traceable to the low survival of plantings in late summer and early fall.

Timothy and Kentucky bluegrass gave definitely poor results for all seasonal periods, and tall oatgrass only slightly better. The explanation for the failure of these grasses lies in the high mortality of the seedlings. While emergence was often observed to be good after planting very few seedlings lived through into the second year. A heavier rate of seeding would no doubt help to insure a stand. This study plainly shows that there is no direct relationship between size of seed and the rate at which seeds should be planted and that capacity of seedlings to survive should be taken into account when seeding rates are planned. In many instances small-seeded species need to be sown at rates equal to those for large-seeded species to get comparable results.

For the three best species (slender wheatgrass, mountain brome, and smooth brome), average survival was highest during the late spring period. Second in order of average survival was early summer, and next, early spring. However, actual survival differences between the three better seasonal periods are not consistent enough so that one can be recommended over another. The remaining three seasonal periods were considerably inferior, with early fall the poorest of all (see tables 3 and 4).

Table 3.--Seedling survival one year after planting six grasses in the subalpine zone, with seasonal and yearly averages by species, 1941-45

Seasonal period	1941	1942	1943	1944	1945	Seasonal Average	1941	1942	1943	1944	1945	Seasonal Average
	%	%	%	%	%	%	%	%	%	%	%	%
	Slender wheatgrass						Tall oatgrass					
Early spring	43.6	8.4	9.0	14.4	22.0	19.4	0	4.0	13.6	8.0	12.4	7.6
Late spring	48.4	6.4	14.4	17.6	34.0	24.2	0	.4	13.6	3.6	11.6	5.8
Early summer	39.0	10.4	25.6	3.6	36.4	23.0	0	0	10.4	1.6	9.0	4.2
Late summer	33.0	17.0	16.4	14.4	16.0	19.4	2.0	0	1.0	1.0	1.6	1.2
Early fall	27.0	20.0	7.0	7.0	18.0	15.8	2.4	0	1.6	2.0	2.0	1.6
Late fall	--	26.0	18.0	15.0	6.4	16.3	--	19.0	6.0	2.0	0	6.3
Yearly av.	38.2	14.7	15.1	12.0	22.5	19.3	.8	3.9	7.7	3.0	6.1	4.5
	Mountain brome						Timothy					
Early spring	40.0	4.0	19.0	19.6	39.6	24.4	3.0	.4	0	.4	6.4	2.0
Late spring	40.0	7.0	22.4	21.0	52.4	28.6	4.0	.4	1.0	0	8.0	2.6
Early summer	39.6	4.0	43.0	15.6	34.4	27.4	8.4	0	2.4	0	11.0	4.4
Late summer	5.6	2.4	10.4	13.0	19.0	10.0	.4	1.6	1.6	0	2.0	1.2
Early fall	7.6	3.0	2.4	11.6	10.0	7.0	3.6	3.6	1.6	.4	4.4	3.4
Late fall	--	5.0	3.6	13.0	22.0	10.8	--	3.6	5.0	0	2.4	2.8
Yearly av.	26.6	4.2	16.8	15.6	29.6	18.0	3.9	1.6	1.9	.1	5.7	2.7
	Smooth brome						Kentucky bluegrass					
Early spring	28.0	6.4	8.4	21.0	21.0	17.0	.4	0	0	0	1.0	.2
Late spring	40.4	3.0	9.0	24.0	44.0	24.0	0	.4	.4	0	.4	.2
Early summer	31.6	6.4	25.0	10.0	35.6	21.8	.4	0	1.0	0	0	.2
Late summer	2.4	1.0	21.0	5.0	11.0	8.0	0	.4	3.0	.4	0	.8
Early fall	4.0	1.0	3.6	9.6	14.0	6.4	0	1.6	2.0	.4	0	.8
Late fall	--	11.0	14.4	8.4	23.0	14.2	--	3.6	2.0	0	0	1.4
Yearly av.	21.3	4.8	13.6	13.0	24.8	15.2	.1	1.0	1.4	.1	.2	.6

Table 4.--Relative plot ratings of 4 replications of 6 species one year after planting, with seasonal and yearly averages by species, 1941-45 1/

Seasonal period	1941	1942	1943	1944	1945	Seasonal Average	1941	1942	1943	1944	1943	Seasonal Average
	Slender wheatgrass						Tall oatgrass					
Early spring	9.0	3.2	3.0	5.0	5.2	5.1	0	1.8	5.2	2.8	4.0	2.8
Late spring	9.5	2.2	4.2	5.8	8.8	6.1	0	.2	4.8	1.2	4.0	2.0
Early summer	8.0	3.8	6.2	1.2	6.8	5.6	0	0	3.0	.5	3.3	1.4
Late summer	7.5	4.0	4.8	4.8	4.5	5.1	.5	0	.5	.5	.8	.5
Early fall	6.8	6.0	2.8	2.2	5.0	4.6	.8	0	.7	.8	.7	.6
Late fall	--	6.2	5.8	5.2	2.8	5.0	--	5.8	2.0	.5	0	1.7
Yearly av.	8.2	4.2	4.5	4.0	5.8	5.2	.2	1.3	2.7	1.0	2.1	1.5
	Mountain brome						Timothy					
Early spring	9.5	1.2	5.8	6.0	9.0	6.3	1.0	.2	0	.3	1.5	.6
Late spring	8.2	2.0	7.0	6.2	9.8	6.6	1.5	.3	.2	0	2.8	1.0
Early summer	7.8	1.0	8.5	5.0	8.3	6.2	3.0	0	.8	0	3.7	1.5
Late summer	1.0	1.0	3.5	4.0	5.2	2.9	.2	.5	.5	0	.8	.4
Early fall	2.5	1.0	1.0	3.5	3.0	2.2	1.5	1.5	.8	.2	1.0	1.0
Late fall	--	1.8	1.2	3.7	5.8	3.1	--	1.5	1.5	0	1.0	.8
Yearly av.	5.8	1.3	4.5	4.8	6.8	4.6	1.4	.7	.6	.1	1.8	.9
	Smooth brome						Kentucky bluegrass					
Early spring	8.0	2.2	3.8	6.2	5.5	5.1	.3	0	0	0	.5	.2
Late spring	9.8	1.0	3.8	6.8	9.8	6.2	0	.2	.3	0	.3	.2
Early summer	7.2	1.8	9.0	4.0	8.2	6.0	.3	0	.5	0	0	.2
Late summer	1.0	.5	6.5	2.0	3.0	2.6	0	.2	1.0	.3	0	.3
Early fall	1.2	.5	1.0	2.5	4.2	1.9	0	.8	.8	.2	0	.4
Late fall	--	3.8	4.8	3.0	5.7	4.3	--	1.2	.8	0	0	.4
Yearly av.	5.4	1.6	4.8	4.0	6.1	4.4	.1	.4	.5	.1	.1	.3

1/ Meaning of ratings: 0, failure; 1-2, very poor; 3-4, poor; 5-6, fair; 7-8, good; 9-10, excellent.

Because of the inconsistent and low establishment of tall oatgrass, timothy, and Kentucky bluegrass, they are not included in further discussion of results.

Precipitation and Survival

Precipitation varied considerably during the growing periods of the 5 years of this study (table 5). In 1943 the precipitation for the growing season was one of the highest on record whereas that for the 1944 growing season was one of the lowest.

Table 5.--Average seedling survival by seasonal period for three grasses (slender wheatgrass, mountain brome, and smooth brome) together with precipitation during July, August, and September (1941-45)

Seasonal period	1941	1942	1943	1944	1945	Average
	%	%	%	%	%	%
Early spring	37.2	6.3	12.1	18.3	27.5	20.3
Late spring	42.9	5.5	15.3	20.9	43.5	25.6
Early summer	36.7	6.9	31.2	9.7	35.5	24.0
Late summer	13.7	6.8	15.9	10.8	15.3	12.5
Early fall	12.9	8.0	4.3	9.4	14.0	9.7
Late fall	--	14.0	12.0	12.1	17.8	14.0
Average	28.7	7.9	15.1	13.5	25.6	17.7
	Precipitation					
	In.	In.	In.	In.	In.	In.
July	1.21	1.27	1.46	.11	1.11	1.03
August	2.22	.85	3.21	.50	1.42	1.64
September	1.62	.86	.65	.01	.45	.72
Total	5.05	2.98	5.32	.62	2.98	3.39

Table 5 also shows the average yearly seedling survivals for the three best species. With the exception of the year 1942, seedling survival during early spring and late spring was good enough to insure successful stands. Early summer was good in 3 of the 5 years. The very poor survival of 1942 is associated with freezing temperatures in the early spring of 1943. This was a year when the snow cover had melted off before May 15. Between May 12 and May 20 there

were unusually low minimum temperatures that caused the surface soil to freeze nightly. This alternate freezing and thawing resulted in heavy death losses.

In 1944, the lowest precipitation year of the five, results were comparatively good for the early and late spring plantings. These better-than-expected results in a very dry spring and summer are attributable to the excellent ground moisture at the time of planting together with the fact that rain after the plantings came at very opportune times.

The rather uniformly poorer establishment of all plantings in late summer and early fall is directly traceable to winterkilling. Seeds planted during these seasonal periods germinate and emerge in the waning days of the growing period. When winter sets in, the seedlings are not well-enough established to withstand the freezing and thawing that takes place. Generally this is most severe in late October and early November when snow is present only in patches or is very thin. Often young seedlings are completely heaved out of the ground. Slender wheatgrass seedlings proved to be the most successful in withstanding this freezing and thawing action.

It is to be noted that survival figures for late fall plantings (see table 5), while considerably lower than for the three best seasons, vary less from year to year. Generally late fall can be relied upon for good stands, but in this study it was definitely inferior as a planting time to early spring, late spring, and early summer. Late fall is generally poorer than the three better seasonal periods because some seeds germinate or start to germinate and then die under the snow. There are thus two risks involved in late fall planting. First, the possibility of there being no late fall season. (An unusually early snow may come as it did during this study in 1941 and preclude a seeding.) Second, there is the hazard of planting just a few days too early with the consequence that much of the seed will germinate, emerge, and then die from freezing and thawing in the late fall months.

Summary

In this study of proper seasonal planting periods for grasses on a high mountain area in central Utah, the order of preference, based on averages, was found to be: Late spring, early summer, early spring, late fall, late summer, and early fall. Seasonal periods and date variations, all based on the development of native mountain brome, were as follows:

Seasonal period	Date variation
Early spring	May 28 to June 29
Late spring	June 30 to July 19
Early summer	July 24 to August 2
Late summer	August 17 to August 22
Early fall	September 1 to September 12
Late fall	September 27 to November 6

Of the six grasses used, slender wheatgrass, mountain brome, and smooth brome in that order, had the highest percentage survival in all seasonal periods. Tall oatgrass, timothy, and Kentucky bluegrass gave very low and erratic establishment. A higher seeding rate would doubtless have helped to obtain satisfactory stands of these three grasses. As this study shows, the relative number of seeds per pound is not necessarily the only criterion governing seeding rates. The ability of seedlings to survive under the conditions prevailing at the planting site should also be considered.

Because the three better seasonal periods occupy a continuous part of the year and because seedling survival is similar during each of the periods, the combined period of good results extended from the time it was first possible to get on the ground until late July. Late fall was next in order of preference, but proved hazardous because of the possibility of early snowfall or premature plantings. Late summer and early fall plantings gave very poor all-around results.

APPENDIX

Recommended Planting Method Based on Study Findings

For those who wish to undertake a large-scale planting in the subalpine zone, the following method is suggested. It is based on the findings of previous studies and experience as well as the foregoing study and has given good to excellent stands. Other less comprehensive plans have resulted in failure.

1. Competition from vegetation already established on the ground should be eliminated. Practically all studies on revegetation have shown that seeds sown or drilled into other vegetation have little chance for survival.

On lands supporting perennial weeds it is best to plow the entire area to be seeded during the summer preceding the actual planting. A one-way disk plow has proved effective on many perennial weed types. Moldboard plows are often better, but treatment costs more. Where perennials are firmly established and tend to form a sod, moldboard plowing is usually necessary. Plowing before seed matures on competing vegetation will greatly reduce reinfestation by undesirable plants. Plowing the year before planting will allow the

soil to settle before seeding operations begin. If the soil has had time to settle it is much easier to gauge the depth of seeding. Drilling on loose soil often results in getting the seed in too deep.

Where an area is supporting annual weeds, such as cluster tarweed and Douglas knotweed, surface cultivation in early spring, followed by planting has proved effective. Shallow wheatland plowing, or thorough surface treatment with a duck-foot weeder or spring-tooth harrow are good methods of reducing weed competition. Most annual weed species have germinated and emerged by the time snow is fully off the ground. The remaining viable weed seeds usually lie dormant until the next spring. Thus, surface cultivation in the early spring kills the serious annual weed competition for the current season. If a grass stand is established soon after, it will suppress weed seedlings that may start the following spring.

From preliminary tests it appears that spraying 2,4-D at a rate of 3/4 to 1 pound an acre is a good control measure for annual weeds. It is important that application be made as early as possible in the spring while ground still has good moisture in the surface 3 inches. Treatment is most effective if done before the weeds reach the 4-leaf stage. Further tests are needed to determine the limitations of this chemical control method, and best dates to make plantings after spraying.

2. Plant before late July. Later plantings will be more liable to damage from either a dry summer or early fall because seedlings are not sufficiently advanced to withstand drought or freezing and thawing. If it is not practical to plant in the spring or early summer then late fall planting is recommended.

3. Use a drill where possible and plant no deeper than 3/4 inch. A drill insures uniformly distributed seed and places the seed at desired depth.

4. If a drill is not available or cannot be used broadcast seed and cover by light harrowing or light disking.

5. Except where soil has a tendency to be naturally moist in summer and fall, a mixture composed of the following species and amounts of seeds per acre will prove satisfactory:

Smooth brome	4 lbs.
Orchardgrass	2 lbs.
Mountain brome	2 lbs.
Slender wheatgrass	2 lbs.
Tall oatgrass	2 lbs.
Total	12 lbs.

If some species are not available, smooth brome can be used alone or with any other one or two species. On naturally moist areas

substitution of timothy and reed canarygrass, meadow foxtail or Kentucky bluegrass for mountain brome and slender wheatgrass can be made. Mountain brome and slender wheatgrass should be from a source that is adapted to high mountains. Much seed on the market of these species is not suited for high elevations. Meadow brome and tomentose brome are useful substitutions for mountain brome and slender wheatgrass.

6. Drill at a rate of 8 to 10 pounds per acre or broadcast at 12 to 14 pounds per acre.

7. Do not graze the area for the entire first year. Then if establishment of the grasses is satisfactory, graze the area lightly toward the close of the second summer season. If establishment could be aided by further protection allow no stock to graze during the second year. After establishment, graze seeded ranges judiciously. Don't allow stock to get on the area while it is still wet from winter snows. Watch the progress of grazing; take stock off when no more than 60 to 65 percent of the current year's forage is consumed, leaving the remaining 40 to 35 percent to protect the soil and to enable the forage plants to maintain their vigor. If land has much slope, 50 percent of the current year's growth should be left.

LIST OF COMMON AND SCIENTIFIC NAMES

Grasses:

Meadow brome	Bromus erectus
Meadow foxtail	Alopecurus pratensis
Mountain brome	Bromus carinatus
Reed canarygrass	Phalaris arundinacea
Slender wheatgrass	Agropyron trachycaulum
Smooth brome	Bromus inermis
Tall oatgrass	Arrhenatherum elatius
Timothy	Phleum pratense
Tomentose brome	Bromus tomentellus

Weeds:

American vetch	Vicia americana
Barbey larkspur	Delphinium barbeyi
Cluster tarweed	Madia glomerata
Common dandelion	Taraxacum officinale
Douglas knotweed	Polygonum douglasi
False carrot	Pseudocymopterus tidestromi
Slimstem cinquefoil	Potentilla filipes
Sticky geranium	Geranium viscosissimum
Sweet sagebrush	Artemisia discolor
Western yarrow	Achillea lanulosa

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U. S. Department of Agriculture
Forest Service, Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 19 March 1950

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SUGGESTIONS FOR TECHNIQUES IN REFORESTATION IN THE INTERMOUNTAIN REGION 1/

By James D. Curtis, Forester

With recent passage of legislation by Congress for rehabilitation of unproductive forest land, many regions have started reforestation programs. The successful establishment of trees, either by artificial seeding or by planting, is not easy in the arid climate of the Intermountain region. Consequently, if the failures of early attempts in reforestation are to be avoided, every precaution must be observed and every instance, where experience has shown a certain course should be followed or shunned, must be recalled and observed.

Artificial Seeding

Artificial forest seeding has been carried out in the Western States, off and on, since 1905. Many of these early trials, and even later ones, were on a large scale and of such varying design that they produced erratic results. Consequently, this method of reforestation was regarded as inexpedient and unreliable.

Recent tests, however, have shown that certain aspects of seeding technique which were either overlooked or not given due weight previously have given encouraging results. While the following guides to technique are not conclusive, they should provide basic framework which can be added to rather than one that needs to be altered by further experimentation. For ponderosa pine on the granitic soils of central Idaho, the following points are fairly well established:

1. Seed and young seedlings must be protected from rodents. Broadcasting or sowing in spots without protection (screens or poison) is an appalling waste of seed except possibly when done on large burns, well inward from the borders, and immediately (i.e., before brush growth begins) after the fire.

1/ The information contained in this statement is drawn from the exploratory but soundly designed and carefully executed tests in seeding and planting by T. E. Maki, and extensive surveys and examinations by C. F. Korstian and F. S. Baker, formerly of the Station staff.

2. Competition from brush, grass, and weeds must be reduced by some means. Sowing immediately after a fire offers a partial solution but on old brush-covered burns some means must be found to reduce competition. Weedings may be necessary during the early years.

3. Fall sowing is better than spring sowing if complete protection is provided. Ordinarily untreated seed cannot be sown early enough in the spring in central Idaho to obtain satisfactory germination. Unless seed can be pretreated to induce very rapid germination, fall-sown seed holds a big advantage over spring-sown seed.

4. Hardware wire cloth (3-to-the-inch mesh) cones furnish sufficient protection against ordinary rodents and birds.

5. Young seedlings must be protected until stems are definitely suberized. Cones should be left in place until about the middle of August in the first growing season.

6. Grazing must be excluded during the first few years.

7. Only about 50 percent of clean and sound ponderosa pine seed can be expected to germinate under the natural conditions encountered in seeding. Allowances must be made for germination failure and drought losses. Fifteen seeds per spot is suggested as a conservative number.

Planting

Considerable experimental planting has been done in the Intermountain region dating from about 1915. The early plantings were confined to Utah and southeastern Idaho; latterly efforts have been directed towards work in central Idaho.

Within the Intermountain region, the greatest obstacle to successful planting is the dearth of available moisture in the root zone that invariably develops early in the growing season when the plant strives to become established. This, together with plant competition, has proved to be responsible for much mortality. Evidently no number of vigorous lateral roots will enable the plant to overcome a lack of sufficient moisture for root absorption and plant growth. Consequently, while some laterals are desirable, a healthy, well-developed taproot, some 12-15 inches long is much more useful and thus more important. It is to be further appreciated that since climate is one of the few uncontrollable factors, it is important to exercise every care in conforming to accepted standards of stock and procedures for lifting, transporting, and planting which are known to be suitable for all other factors involved. Some of these criteria are as follows:

1. Stock should be raised from a native seed source and if possible seed should be collected from trees of good vigor and good form. This is a silvical axiom all too often overlooked through expediency, "economy," or lack of facilities for collecting seed.

2. Planting sites, both general areas and spots within an area, should be critically selected. This means choosing planting areas where conditions are not unduly severe and choosing planting spots where shade and protection are provided by stumps, logs, rocks, living brush, or hummocks.

3. Plant at the proper time. In spring operations, plant immediately after snow recession and restrict planting to a short period thereafter. Refrain from fall planting unless autumnal rainfall is adequate to moisten the top 15 to 18 inches of soil.

4. Use husky stock. Stock should be heavily culled so that firm stems, taproots of not less than 12 inches, and a fair number of laterals characterize the plants. Stock of 2-1, 1-2, or 2-0 will probably fulfill these requirements.

5. Site preparation is necessary. This should take the form of reducing plant competition no matter what its kind. Where snag stands happen to be heavy, snag removal may be necessary, certainly desirable.

6. Exclude or restrict grazing during the early life of the plantation. Direct damages from trampling and indirect damage from sloughing of soil is real and considerable where grazing animals are present.

7. Sacrifice speed for care. The following rules should be applied from the time of nursery lifting to the planting of stock in the field: time the operations carefully; avoid root stripping, especially of the taproot; pack carefully to avoid overheating and drying out of the smaller roots, even in cloudy weather; exercise care in setting the plant vertically at the correct depth with roots spread out; and tamp sufficiently. Though these rules are familiar, unfortunately they are too often neglected in favor of establishing production rates and records, actually of little importance in the final analysis.

All of these criteria emphasize careful planning if any degree of success in reforestation is to be achieved under the severe climatic conditions of the Intermountain region.

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STOCKING OF LOGGED PONDEROSA PINE LAND IN CENTRAL IDAHO

By

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STOCKING OF LOGGED PONDEROSA PINE LAND IN CENTRAL IDAHO 1/

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INTRODUCTION

Three main problems confront the silviculturist in managing forested land--the removal of merchantable timber, the management of the residual stand, and the securing of reproduction to supplement that which remains after logging. The first is generally considered to be difficult enough; the second and third even more so. The actual processes of tree marking, felling, bucking, skidding, and hauling are straightforward procedures requiring manpower and machinery. But just exactly how this is done is of vital concern to the forester because while he is greatly interested in the volume per acre that can be removed from the land at a profit, he is even more interested in the condition of the area after logging, the loss of trees during the process, subsequent mortality, and the growth and development of the trees that are left.

Having decided how much volume per acre and what kind and size of trees composing that volume will be removed, the forester immediately reflects on what will be growing on the area five years after logging because this growing stock will determine not only future growth per acre but the approximate dates of later harvests. In other words, he strives for a completely stocked stand from 1-year-old seedlings to trees which will be mature at the end of the next cutting cycle. Some of these trees will have been destroyed during the logging; others may die shortly thereafter due to insects, pathogens, or wind. Fire must be excluded if further losses are to be prevented. The number of trees of the younger age classes and their distribution are therefore extremely important from the standpoint of future management since these stems are the basis of later cuts.

These considerations are particularly true of central Idaho where many factors, particularly the lack of seasonal precipitation or regular heavy seed crops and the presence of competing vegetation, militate against the successful establishment of natural reproduction.

1/ This study was conceived and designed by C. A. Connaughton. The field work, done in 1932, was carried out by T. E. Maki, E. L. Mowat, A. Fawcett, and William David. Compilations were made by E. L. Mowat, T. C. Pender, and R. W. Dingle.

At the present time (1950), ponderosa pine is the most valuable commercial tree species in central Idaho. It has been estimated[2/] that this species leads all others in distribution over the area. Ponderosa pine has always comprised the largest percentage of the total volume cut in the Intermountain Region since cutting began in Idaho in 1863 when a mill was established in the Boise Basin. In general, its stands are the most accessible, its trees the largest, and its lumber value the highest of all species native to the region.

Object of Study

To determine the amount and distribution of reproduction and advance growth from 1-year seedlings to timber size trees on cut-over areas representative of central Idaho, a study of cut-over areas in four locations where the date of logging preceding the examination varied from 7 to 26 years, was instituted in 1932. Table 1 presents some information regarding these areas and figure 1 shows their location.

Table 1.--Name and location of areas, date of logging, and number and volume by percentage of trees removed

Name	Location	Date of logging	Years since logging	Trees removed	
				Number	Volume
				Percent	Percent
Clear Cr. N. F.	T8N, R6E, Sec. 29 32	1924-25	8	53	79
Private	T8N, R5E, Sec. 36	1924-25	8	86	98
Lowman	T9N, R7E, Sec. 27	1906-07	26	37	58
Pearsol Crook	T14N, R4E, Sec. 21	1924-25	8	48	81
Rock Flat East	T19N, R2E, Sec. 35	1925-26	7	58	80
West	T19N, R2E, Sec. 36	1924-25	8	53	83

Areas Studied

The topography of central Idaho is rough, consisting of major and minor drainages and varying in elevation from 3,000 to 10,000 feet. Ponderosa pine, together with some Douglas-fir on north slopes, is found at elevations of 3,000 to 7,000 feet above sea level. All of the study areas are within the middle altitudinal range of ponderosa pine in this

2/ United States Department of Agriculture. The national forests of Idaho. Misc. Circ. 61. 34 pp., illus. 1926.

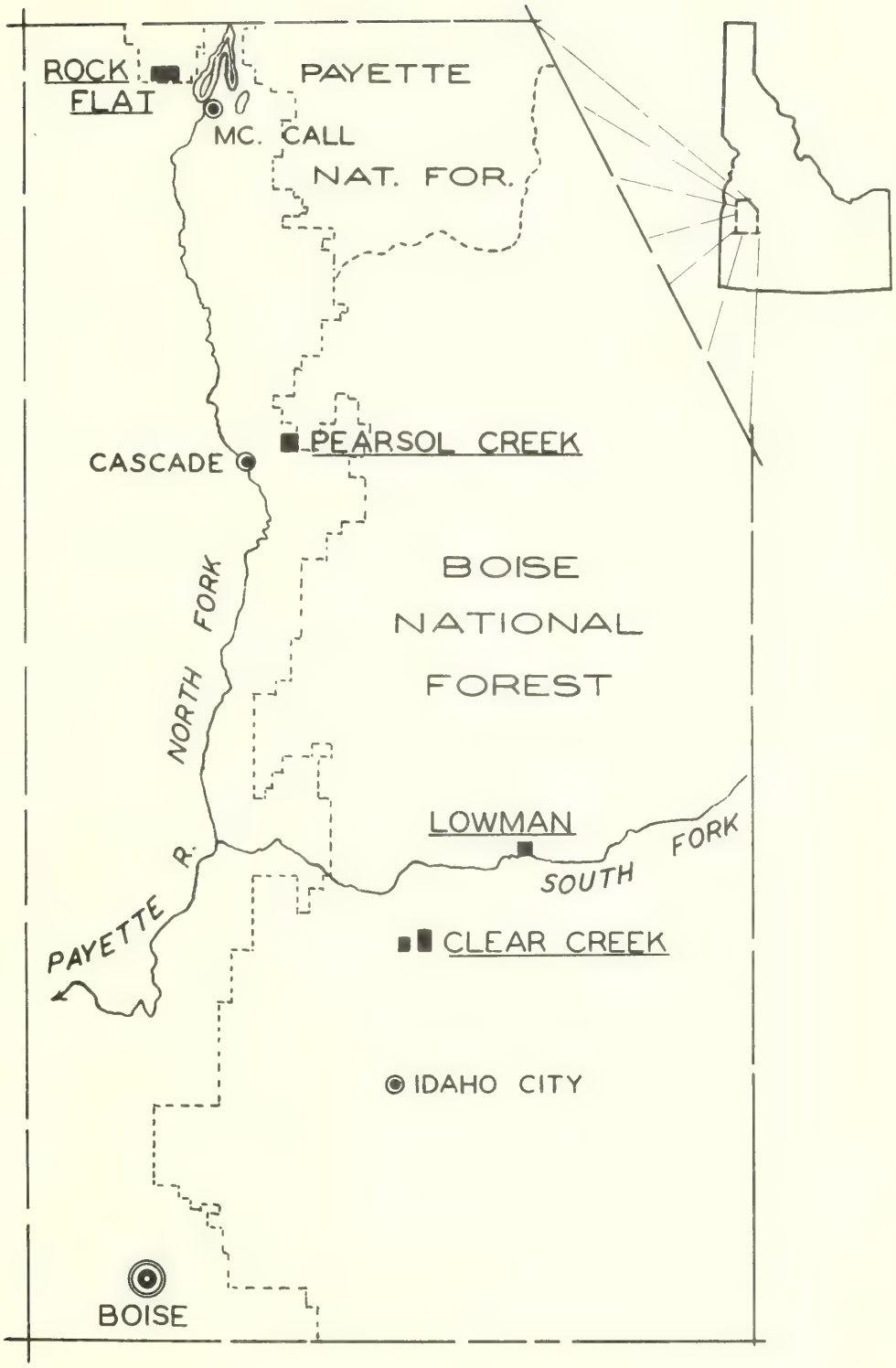


Figure 1. Location of study areas.

(AGRICULTURE - OGDEN)

region (4,000 to 5,000 feet above sea level). Within the series, small differences in climate, altitude, aspect, slope, and soil are reflected in stand structure and composition, form and rate of growth of the trees, and frequency and abundance of reproduction. Site quality, according to the interregional classification, is largely in classes III and IV, with a small proportion of area in sites I, II, and V. Topography of the tracts studied is from rolling to moderately rough and steep--about average for the ponderosa pine lands bearing commercial stands.

All areas studied fall in the ponderosa pine type of central Idaho; soils are characterized by gravelly, sandy loams of granitic origin which vary in depth depending on topography. The only exception is the Rock Flat area where the soils are fine clay loam of basaltic origin, red-brown in color, decidedly sticky when wet and lacking the high proportion of gravel common to the pure granitic soils of southern Idaho.

Of greatest importance in the region is the amount of annual and seasonal (May, June, July, and August) rainfall which, seldom exceeding 25.00 and 5.00 inches, is generally insufficient to insure germination and establishment of reproduction annually. The granitic soils have a low water retaining capacity and hence the seedlings endure a continuous struggle for survival after germination. When a medium to heavy seed year occurs and there follows a favorable spring and early summer (rainfall higher than average), ample establishment of reproduction results and invariably persists to an appreciable degree.

Previous Studies

Baker[3/] considers that, for establishment, 100 seedlings per acre are an adequate minimum, that 600 seedlings per acre are ideal, and that 1,500 seedlings per acre are a safe maximum. He found that in the Boise Basin where 90 percent of the volume was removed, there were 142 stems per acre under 4 inches d.b.h. When 35 to 65 percent was cut, there were 442 stems per acre; in light cuttings, when up to 35 percent was cut, 510 stems per acre were found. These figures compare with 475 stems per acre in virgin stands. Baker concluded that for all except north exposures, and unless over 80 percent by volume of the stand is cut, some 500 trees per acre may be expected in the first decade after cutting.

While the study was not strictly comparable because of sizes tallied, Miles[4/] found on a 10 percent cruise of 1,400 acres on Pearsol Creek that after a 76 percent cut by volume, there were only 16 trees per acre of the 2 and 4 inch d.b.h. classes. On other areas in the same general vicinity, however, Baker[5/] found as high as 6,380 seedlings per acre. Obviously, there is considerable variation in reproduction per acre after logging.

3/ Baker, F. S. Study of cut-over areas in western yellow pine, Boise Basin, Idaho. U. S. Forest Service, Ogden, Utah. 1922. (unpublished).

4/ Miles, Clark. Notes on certain area studies. 9 pp. U. S. Forest Service, Ogden, Utah. 1929 (Unpublished).

5/ Baker, F. S. Western yellow pine in southern Idaho. 37 pp. U. S. Forest Service, Ogden, Utah. 1922. (Unpublished).

Throughout southern Idaho it is a common and accurate observation that areas which have been cut over, regardless of the amount of volume per acre removed by logging, become restocked by natural means providing there has been no invasion by fire. This is even true of areas denuded by placer mining which represents the extreme in timber stripping. On these areas, where no semblance of a soil horizon exists and where seedbeds are as severe as any that can be found, it is significant that establishment and growth of reproduction occurs at all. In some instances the progress may be slowed by the invasion of brush but the end result is the same. Given sufficient time, it would appear then that ponderosa pine is a hardy and persistent species capable of reproducing itself under almost any condition, providing fire is excluded.

There is, however, another aspect of the situation that must be considered involving two important factors which can easily be overlooked or at least not fully appreciated. First is the question of the amount and distribution of seedlings and saplings destroyed, directly or indirectly, as a result of logging. Mowat[6/] in an examination of seven 10-acre sample plots in the Boise Basin found that 1,070 seedlings and saplings, 7.5 poles, and 0.7 merchantable trees per acre were destroyed in the operation of tractor logging. An additional 544 seedlings and saplings and 6.2 poles per acre were killed by piling and burning slash. It can be readily appreciated, therefore, that loss of valuable, future crop trees can be substantial. Considering the time required for these trees to establish themselves, the timber producer, public or private, can ill afford such drastic losses.

It is fully appreciated that no timber extraction can take place without damage and loss to growing stock. It becomes a task, then, of reducing logging losses to a minimum, which should be given a priority second only to fire prevention. This can be accomplished only by a full contract agreement reinforced by close and constant cooperation with woods crews during the operation. This is a phase of timber management that pays substantial dividends in the form of sufficient growing stock per acre suitably distributed in future cuts.

The second factor involves the rate of reproduction establishment. Figures are often deluding. The question is, if through logging and slash disposal a 30 percent reduction in young growing stock can be expected, how long will it take to reacquire this loss and perhaps gain what is necessary to have a sufficient number of stems per acre? Cutting timber in such a way that, everything considered, this time is reduced to a minimum should be the aim of those responsible for ponderosa pine management and research. More observations and investigations are needed to make this possible.

6/ Mowat, E. L. Damage by logging and slash disposal in Idaho ponderosa pine. Jour. Forestry 38:247-255. 1940.

The areas covered in this study are of more than ordinary interest because they represent some of the earliest cutting on private and national forest land, dating as far back as 1906. All logging was done by horses. Thus, an opportunity is afforded to examine these early cut areas and find out the amount, kind, and distribution of reproduction on them.

NATURE OF CUTTINGS

As table 1 indicates, the cuttings varied greatly in severity and while the study was largely confined to national forest areas some private land in Clear Creek was included. Although this report presents and discusses differences found in these cases, no implication is intended that the results apply to private cut-over land in general.

Clear Creek - The marking rules prescribed that not less than 85 percent of the live ponderosa pine should be marked for cutting. All marked diseased trees and all unmerchantable dead trees on the sale area were cut provided that such trees did not exceed an average of one per acre for the entire area.

On public land, fuel for loading-donkeys was free if taken from unmerchantable trees or the tops of merchantable ones. Merchantable pine and Douglas-fir used for construction were to be paid for at prevailing rates.

Lowman - In this early sale, it appears that the marking rules and supervision were unusually stringent for the times but of interesting significance. No living trees, including those to be used for chutes and other construction, were to be cut until marked by the forest officer. "All marked and all dead timber sound enough for lumber of any merchantable grade shall be cut. Unmarked living trees which are cut, marked trees left uncut, timber wasted in tops, stumps, and partially sawed logs and dead timber standing or down which is merchantable in the judgment of the forest officer...which is not removed...shall be scaled and paid for at double the agreed contract price."

An interesting and commendable clause of this contract fixed a penalty for damage to standing unmarked trees regardless of size. "No avoidable damage shall be done to the young growth or to trees left standing and no trees shall be left lodged in the process of felling. If live trees not marked for cutting are injured in the process of logging under this contract when such injury could have been prevented with reasonable care, full payment shall be made for their total contents in board feet, log scale, at twice the stumpage price fixed by the contract.

"Work may be suspended by the forest officer in charge if the regulations contained in this contract are disregarded. The violation of any one of the foregoing regulations, if persisted in, shall be sufficient cause for the forester to revoke this contract and to cancel all permits for other privileges."

Pearsol Creek - The cutting contract for this area required that not less than 75 percent by volume of the merchantable live timber down to 12 inches d.b.h. be marked for cutting.

Rock Flat - Cutting rules provided that not less than 85 percent of the total stand of merchantable live timber or trees 12 inches and over d.b.h. should be marked for cutting.

METHOD OF STUDY

Field procedure - Lines were run every 5 or 10 chains from reference points and with circular ¼-acre sample plots at intervals of 2½ or 5 chains, resulting in 10 percent sampling for some areas and 5 percent for others. Only a portion of the full area of most of the cutting units was covered.

On a strip 10 links wide and 1 chain long on the cruise line and just preceding each plot center, reproduction (up to 3.5 inches d.b.h.) was tallied by species and by size classes. Subsequent reproduction (i.e., seedlings originating after logging) was segregated from advance reproduction (i.e., seedlings originating before logging).

Stocking of the area was determined by a tally of quadrats each 25 links long and 21.8 links wide in a continuous strip along the transect line. This size of quadrat, containing 242 square feet was based upon a desirable stocking of 180 trees per acre, evenly distributed, as 100 percent. Each quadrat was recorded as stocked if it had one or more living trees on it, and the size-class of trees comprising the stocking (reproduction, poles, or saw log trees) was noted by code numbers. In order to approximate stocking before logging, the presence of stumps or dead trees was also noted.

The record of reproduction was tabulated in stand table form, the factor of aspect being added to the type-age-site division. The quadrat stocking data were compiled to show original and present stocking percentages on each aspect of each type, both total stocking and by each of the three size-classes of trees.

The quadrat stocking percentages were subjected to a critical analysis in various ways. In general it can be assumed that the survey data yielded samples of areas sufficiently reliable for purposes of the study.

While lodgepole pine, Engelmann spruce, and alpine fir were tallied separately, they have been included with Douglas-fir in the compilations since their numbers were small and irregularly distributed.

RESULTS BY AREAS

Clear Creek National Forest Land

Reproduction - When aspects are considered, the north aspect has by far the largest total reproduction (up to 3 inches d.b.h.) as can be seen from figure 2. The creek bottom has the least. All other aspects have from one-third to one-half the reproduction of the north aspect. Obvious also, is the preponderance of Douglas-fir over ponderosa pine, particularly on north aspects. For all aspects, there is a dearth of post-logging reproduction in the 7 years since logging.

When aspects are ignored and the two main types of ponderosa pine and Douglas-fir are considered (fig. 3), it is seen that in the former type, ponderosa pine reproduction is only slightly in excess of Douglas-fir; in the Douglas-fir type, there is but a modicum of pine. For both types, the amount of reproduction since logging is extremely small.

Quadrat stocking - The most striking fact gleanable from figure 4 is the low proportion of quadrats bearing poles compared to the higher proportion bearing reproduction. This holds true for both types. After cutting, however, there is a much more satisfactory distribution of quadrats bearing trees of different sizes on national forest than on private land. Also by comparison, it can be seen that loss by cutting affected stocking more adversely on private land than on national forest land. Ideally at least, the percentages supporting the three classes of trees should be equal.

Clear Creek Private Land

Reproduction - Considering aspects only, the north aspect has, like the national forest land, by far the most reproduction and the creek bottom the least (fig. 5). This area differs sharply from national forest land in the amount of reproduction, both pine and fir, on the ridge aspect and, to a lesser extent, the amount of both species on the south, east, and west aspects.

When aspects are ignored and types only considered, it can be seen from figure 3 that Douglas-fir predominates in both types. It can be seen further that there is a dearth of post-logging reproduction in both types. Far more interesting, there is much more reproduction (nearly twice as much totally) on private land where some 98 percent of the volume and 86 percent of the number of trees were removed than on national forest land where only 79 percent of the volume and 53 percent of the number of trees were removed.

Quadrat stocking - It is to be noted and appreciated from figure 3 that reproduction per acre before logging on private land is considerably greater (and very much greater in the fir type than on Government land). In view of this it is not difficult to understand why there resulted full stocking in the fir type on private land and only 61.5 percent stocking on Government land. More significant, however, is the fact that even

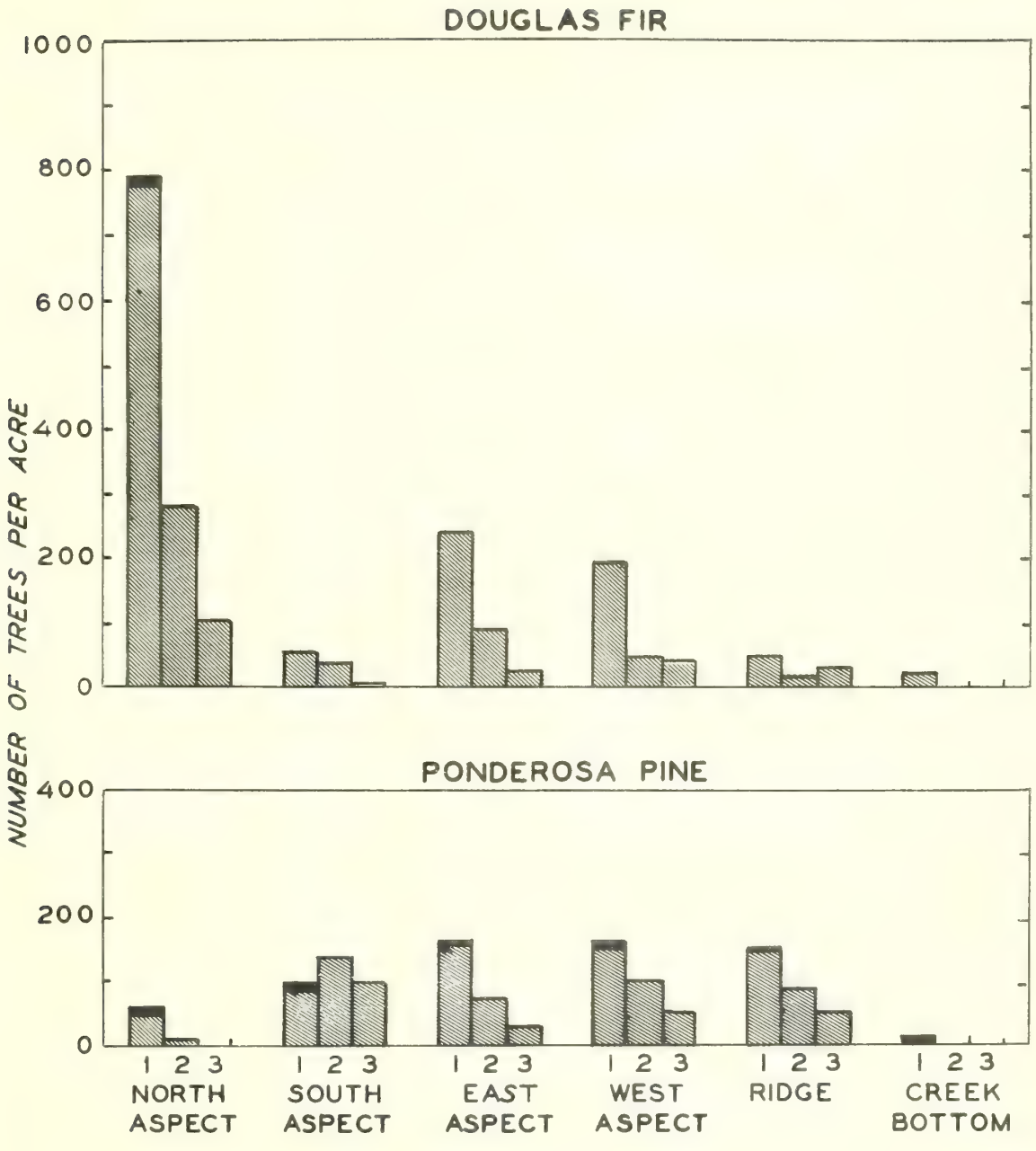


Figure 2. Reproduction of Douglas-fir and ponderosa pine by aspects and size classes before and 7 years after logging on Clear Creek area (Boise National Forest). Logging done in 1924-25 season.

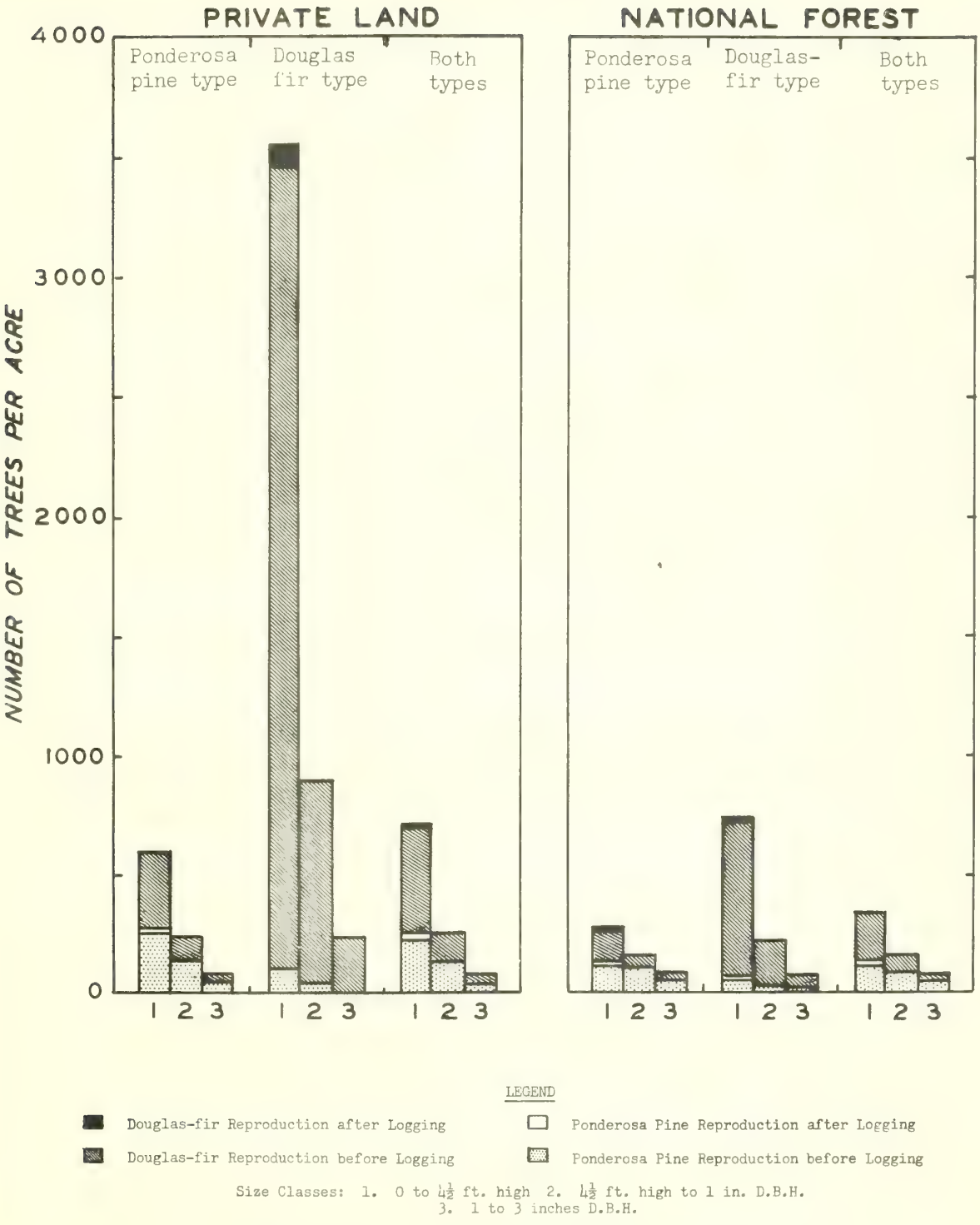
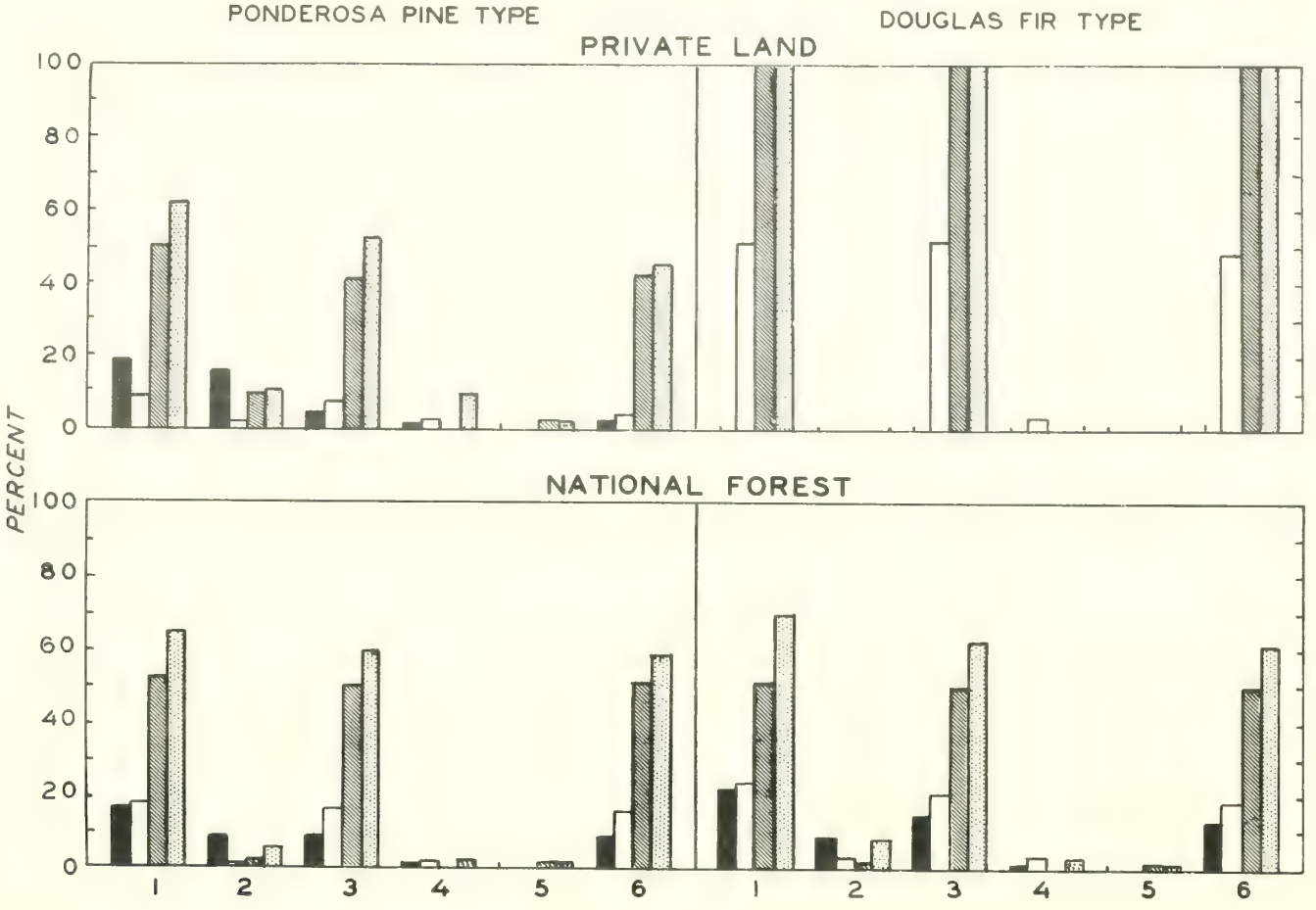


Figure 3. Reproduction of ponderosa pine and Douglas-fir within their respective types before and 7 years after logging on private and national forest land (Clear Creek area).


PONDEROSA PINE TYPE
DOUGLAS FIR TYPE
PRIVATE LAND
NATIONAL FOREST
PERCENT
100
80
60
40
20
0
1
2
3
4
5
6
LEGEND
Timber, 9.6 in. D.B.H. and over
Poles, 3.6 to 9.5 in. D.B.H.
Reproduction, 0 to 3.5 in. D.B.H.
All Sizes
Condition Classes:
1. Stocked before logging
2. Loss by cutting
3. Stocked after logging
4. Loss due to subsequent death
5. Gain due to subsequent reproduction
6. Stocked in 1932

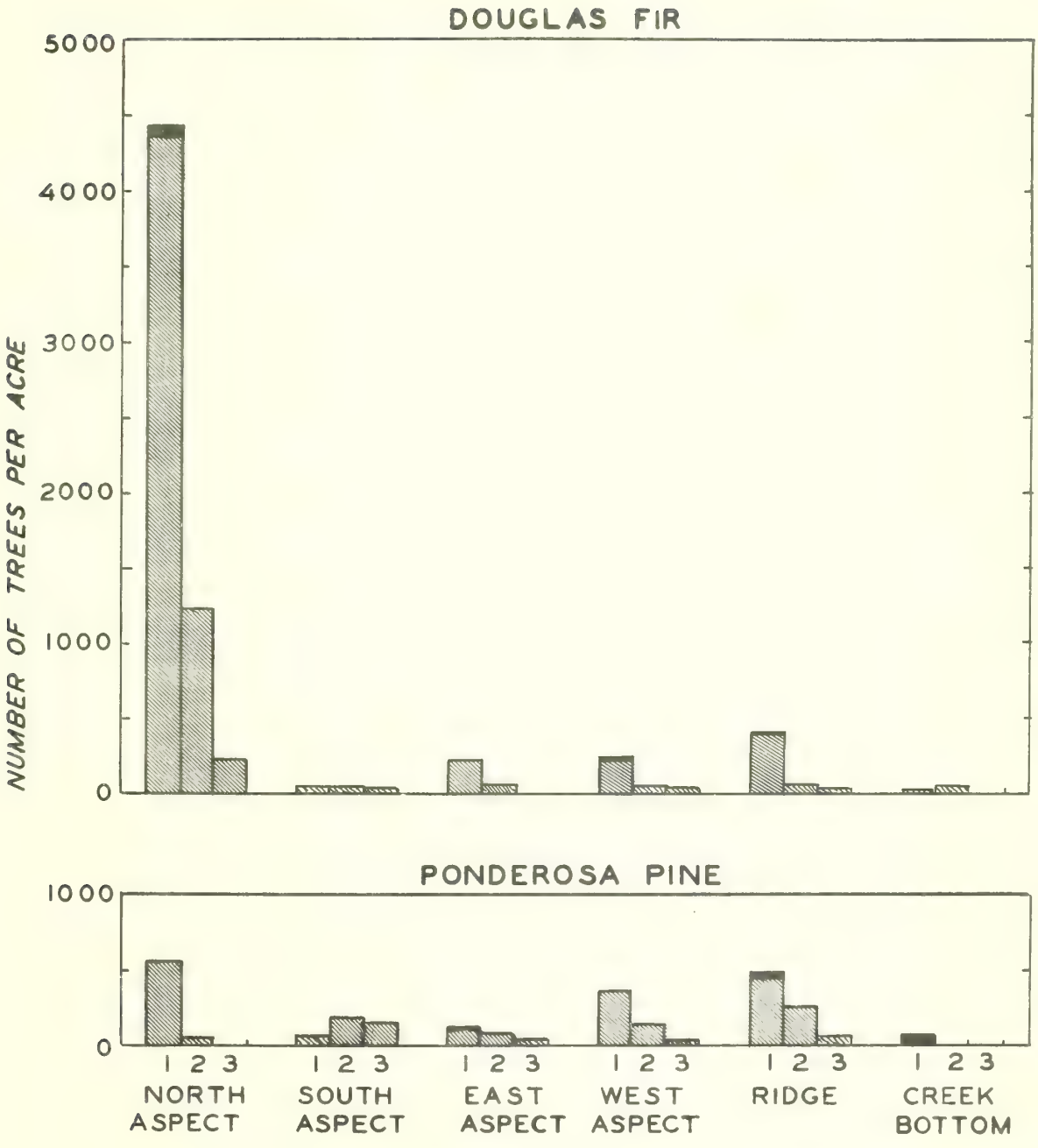


Figure 5. Reproduction of Douglas-fir and ponderosa pine by aspects and size classes before and 7 years after logging on Clear Creek area (private land). Logging done in 1924-25 season.

with high numbers of reproduction per acre on private land, the stocking in the pine type on Government land is not only higher than on private land but is constituted of a high proportion of reproduction, poles, and timber. Likewise the representation of size classes in the fir type is more equitably distributed even though the stocking per acre is lower.

Lowman Area

Reproduction - The most impressive fact on the Lowman area is the amount of postlogging reproduction which exceeds, in many instances by a wide margin, the amount of prelogging reproduction. This relationship holds true regardless of aspect or forest type (figs. 6 and 7). Notable, too, as in Clear Creek, is the small amount of reproduction of all kinds in the creek bottom and the abundance on the ridge aspect. The greatest amount of this reproduction as would be anticipated, is in the youngest age class (0 to 4.5 feet in height). The south aspect has less reproduction per acre than all except the creek bottom. Only on the north aspect does postlogging Douglas-fir reproduction outnumber the pine, although it is liberally represented in the ponderosa pine type.

Quadrat stocking - This area, as can be seen by referring to figure 8, was well stocked (68 percent in the ponderosa pine type and 80 percent in the fir type) before logging with the result that stocking after logging was still strikingly high (80 percent and 89 percent) for both types. There is a slightly more desirable stocking in the fir type from the standpoint of size distribution than in the pine type.

Pearsol Creek Area

Reproduction - Most striking on the Pearsol Creek area (see fig. 9) is the negligible amount of postlogging reproduction which has appeared during the 7 years since logging. Noteworthy also is the greater proportion of pine over fir on all aspects except north and creek bottom, the latter running lowest of all aspects as in previous areas. When the area is considered by separate types (fig. 7) it can be seen that there is more fir in proportion to pine in the Douglas-fir type than there is pine in proportion to fir in the pine type. Here again, the largest proportion of reproduction is in the youngest age class and, again as at Clear Creek there is a dearth of postlogging reproduction.

Quadrat stocking - Reference to figure 8 shows that in each type as in the case of Clear Creek Government land, there has been a slight decrease in stocking in both types in the 8 years after cutting. It can be seen that there is a fair representation of age classes on the percentage of area stocked and like the Clear Creek area the gain in stocking from reproduction subsequent to logging has been discouragingly meager.

Rock Flat Area

Reproduction - On Section 35 of the Rock Flat area, only east and west aspects were involved. The reproduction per acre on east and west aspects is less than for any comparable aspects of the other areas

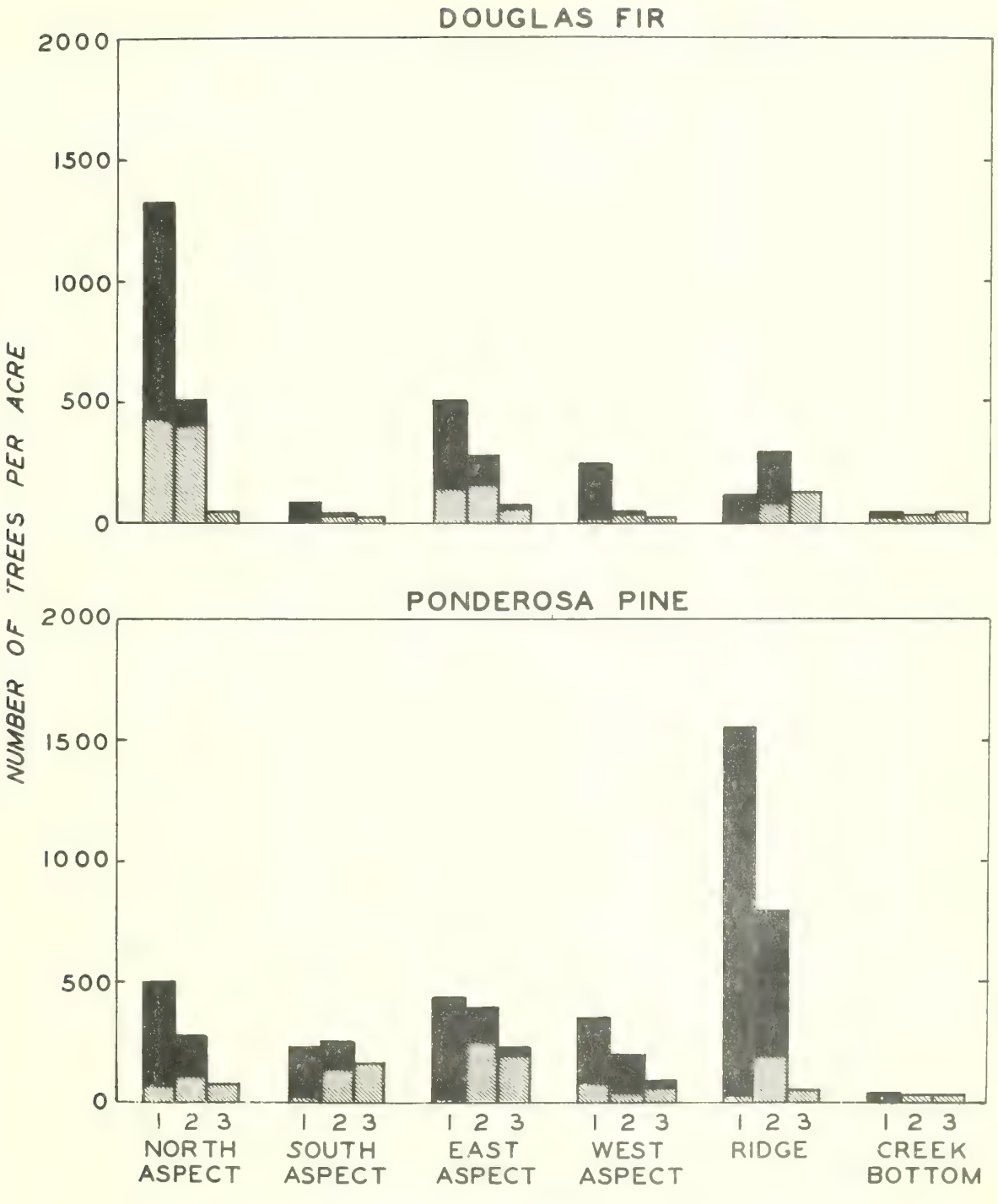


Figure 6. Reproduction of Douglas-fir and Ponderosa pine by aspects and size classes before and 26 years after logging on Lowman area (Boise National Forest). Logging done in 1906-07 season.

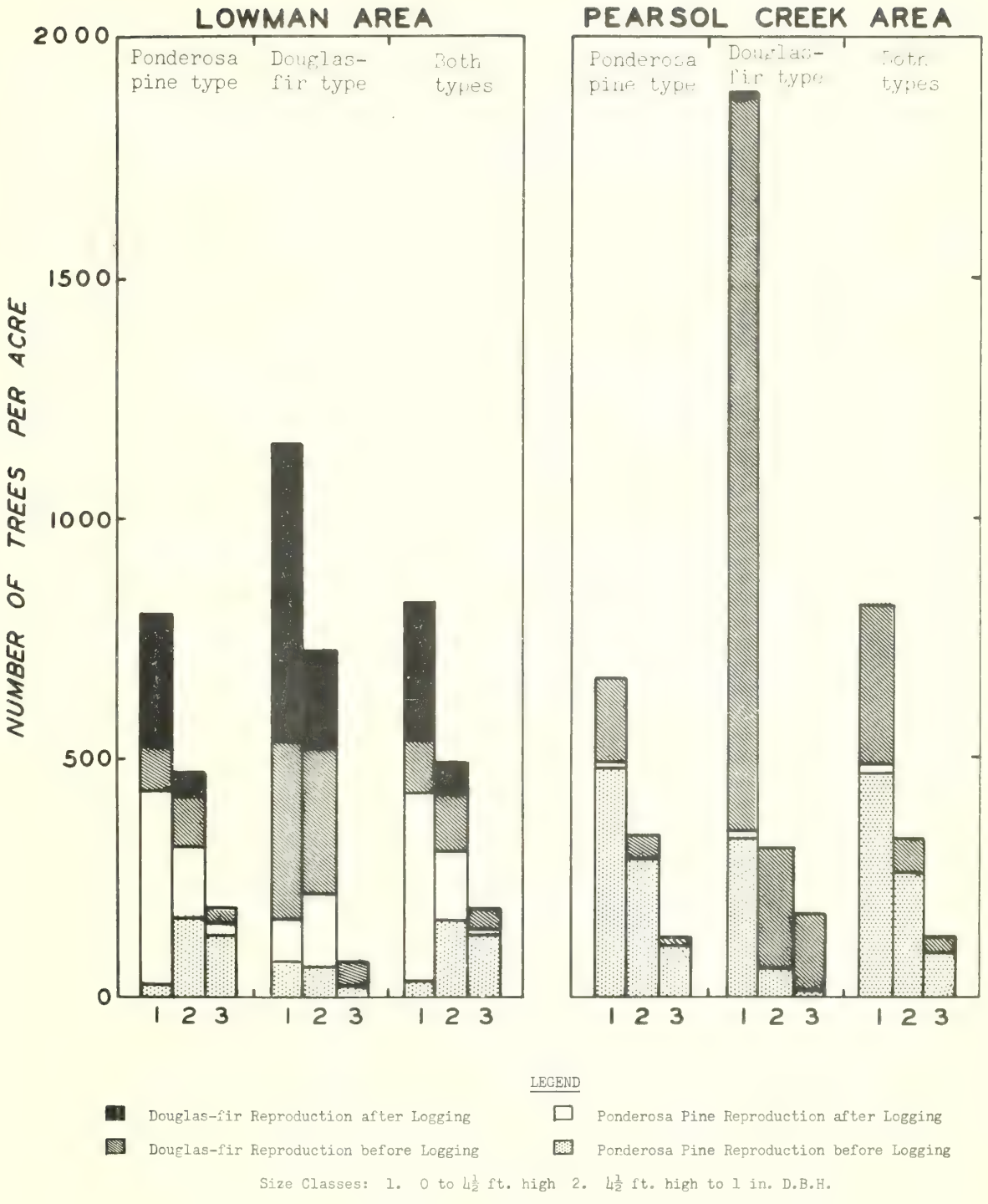


Figure 7. Reproduction of ponderosa pine and Douglas-fir within their respective types before and after logging on the Lowman and Pearsol Creek areas. (Lowman area logged in 1906-07; Pearsol Creek in 1924-25.)

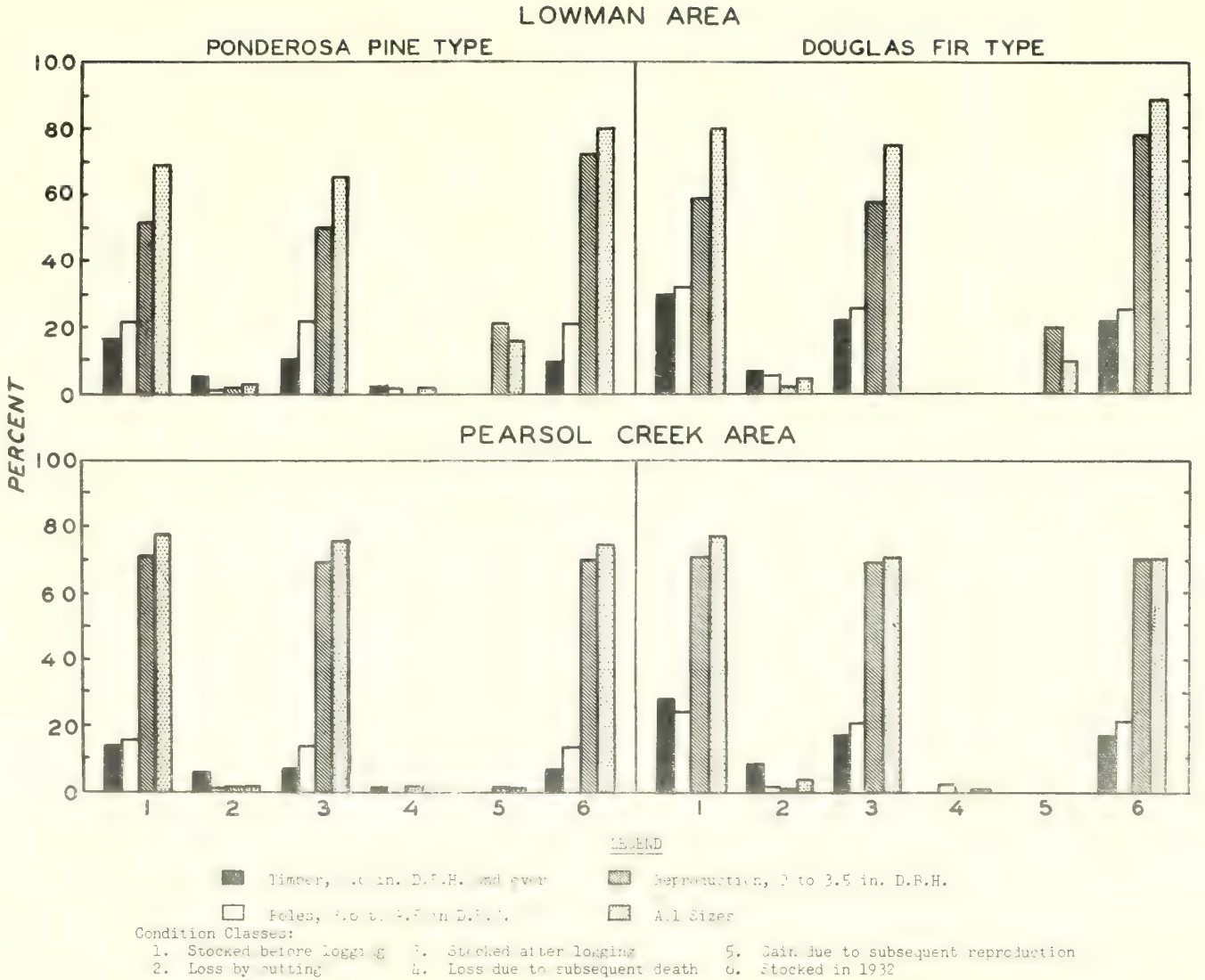


Figure 8. Gains and losses in reproduction and total stocking by percent of quadrats stocked in two forest types on Lowman and Pearsol Creek areas.

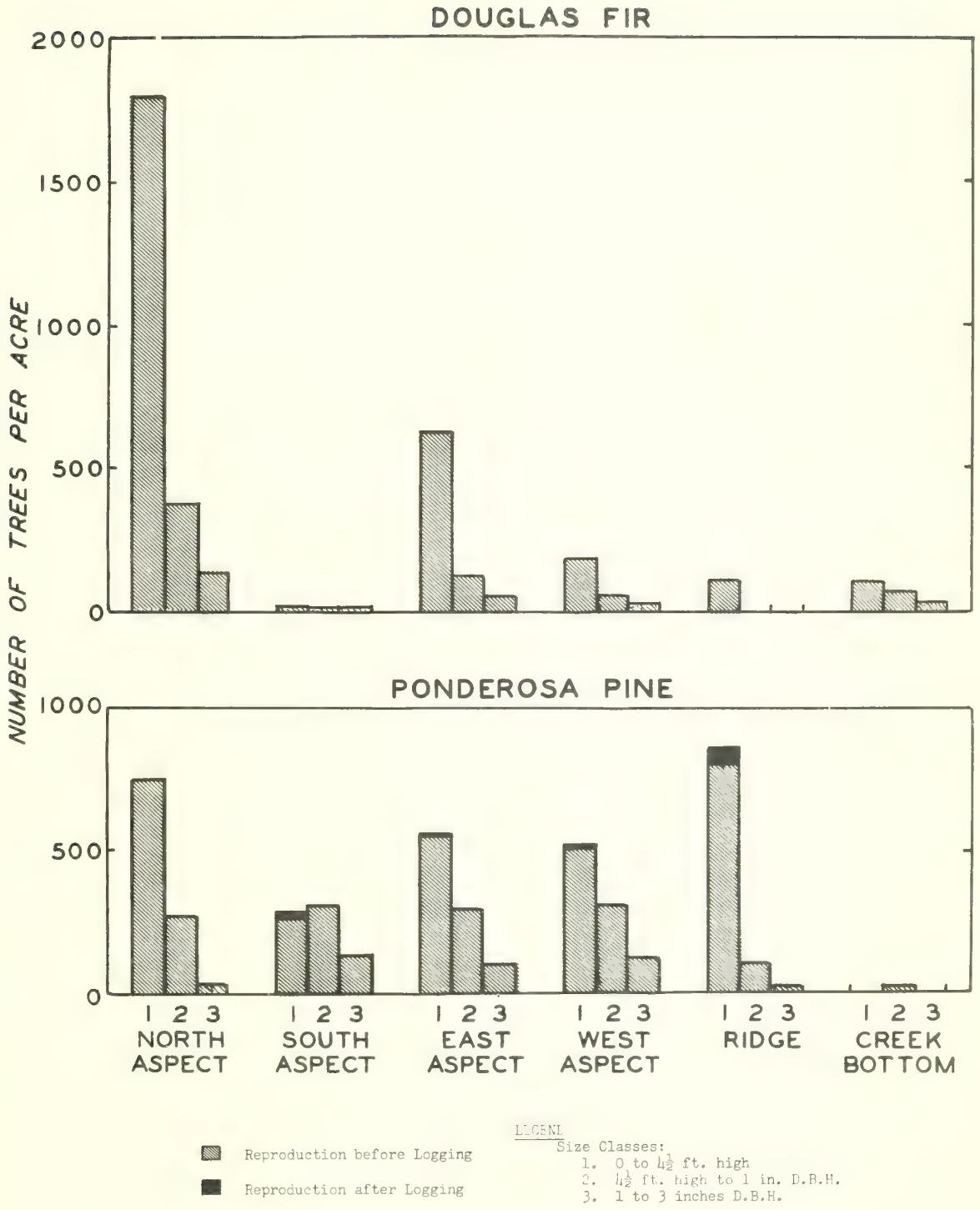


Figure 9. Reproduction of Douglas-fir and ponderosa pine by aspects and size classes before and 7 years after logging on the Pearsol Creek area.

studied (fig. 10). Very little reproduction has established itself during the 7 years since logging. On both aspects there is substantially less ponderosa pine than there is Douglas-fir.

On Section 36, where only north, south, and west aspects were encountered, there is even less reproduction of both species, particularly on north and south aspects. On the west and south aspects there is more pine in relation to fir than on Section 35 but for the three aspects as a group, fir predominates. There has occurred no postlogging reproduction on north and south aspects and very little on the west aspect in the 8 years since logging. The same general relationship of Douglas-fir preponderance and a paucity of postlogging reproduction holds true when types rather than aspects are considered except, of course, that there are higher numbers of pine and fir per acre (fig. 11). In both types the largest proportion of reproduction is in the smallest (0 to 4½ feet tall) age class.

Quadrat stocking - In Section 35 there are more quadrats stocked with reproduction than other classes although distribution of all classes is fairly well represented, excepting timber in the ponderosa pine type (fig. 12).

Section 36 shows somewhat similar relationships within and between types except that there is lower stocking in each type than in section 35, and also fewer quadrats stocked by the various kinds of reproduction. This area, in common with Clear Creek and Pearsol Creek shows a decrease in stocking since logging.

GENERAL RESULTS

The question might now be asked: "What results common to all areas and what results uncommon to all areas appear to be of particular significance?"

Reproduction before and after logging - The greatest amount of postlogging reproduction per acre (0 feet tall to 3 inches d.b.h.) occurs on the Lowman Area and exceeds substantially the amount on each of the other areas. This holds true for both species in both types and for the two species where aspects alone are considered. The most striking feature of the Clear Creek, Pearsol Creek, and Rock Flat areas is the scarcity of postlogging reproduction compared to prelogging reproduction. For all areas the greatest amount of total reproduction occurred on either the north or ridge aspect and least on the creek bottom aspect. On all areas, for each aspect and for each type, the greatest amount of reproduction is in the 0 to 4½ feet height class, with the exception of a single south aspect on Clear Creek.

On all areas there is a higher number of seedlings and saplings per acre in the Douglas-fir type than in the ponderosa pine type and, in addition, more Douglas-fir reproduction in the fir type than ponderosa pine reproduction in the pine type. It can be seen, too, that with the

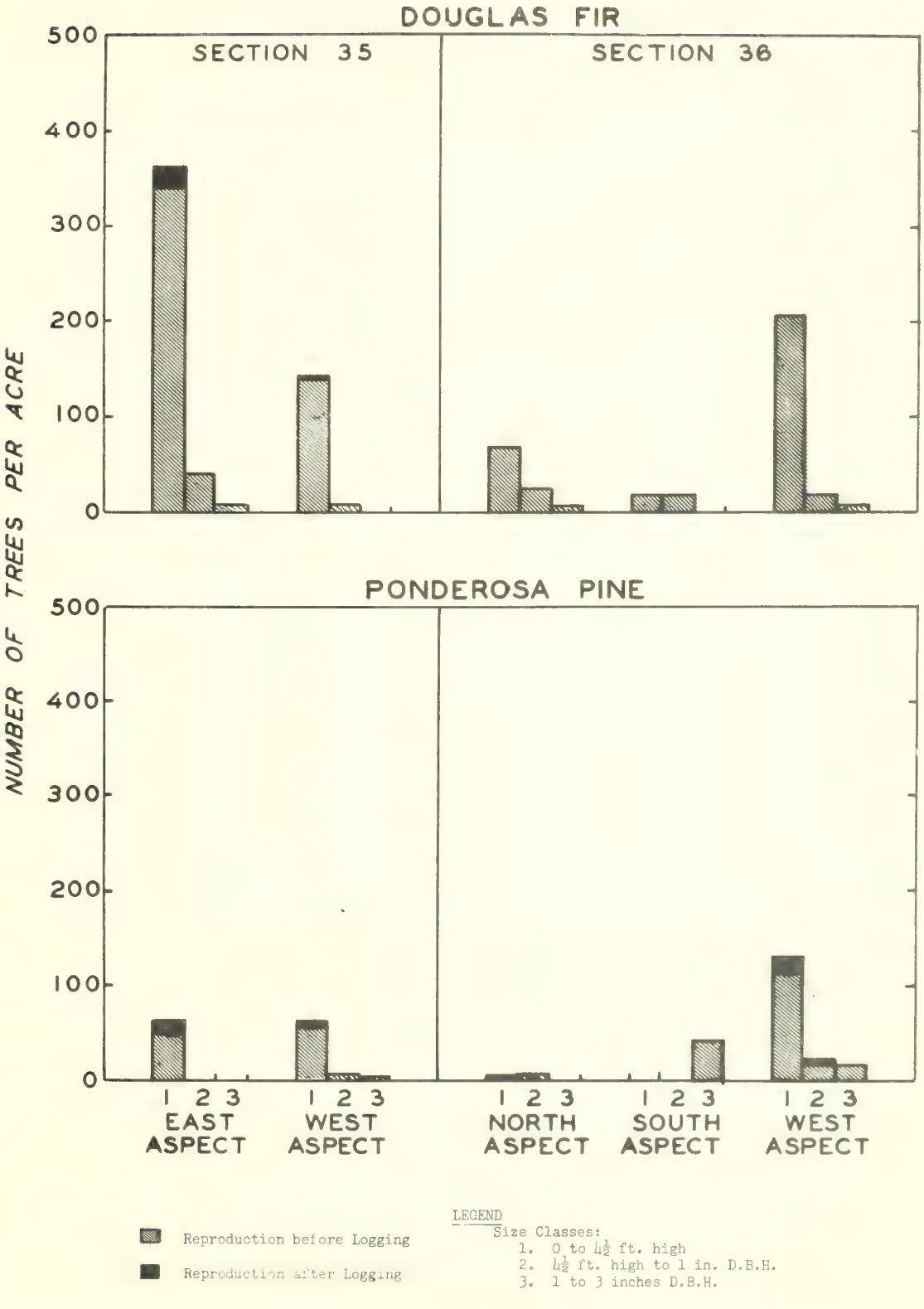


Figure 10. Reproduction of Douglas-fir and ponderosa pine by aspects and size classes before and 7 years after logging on the Rock Flat area.

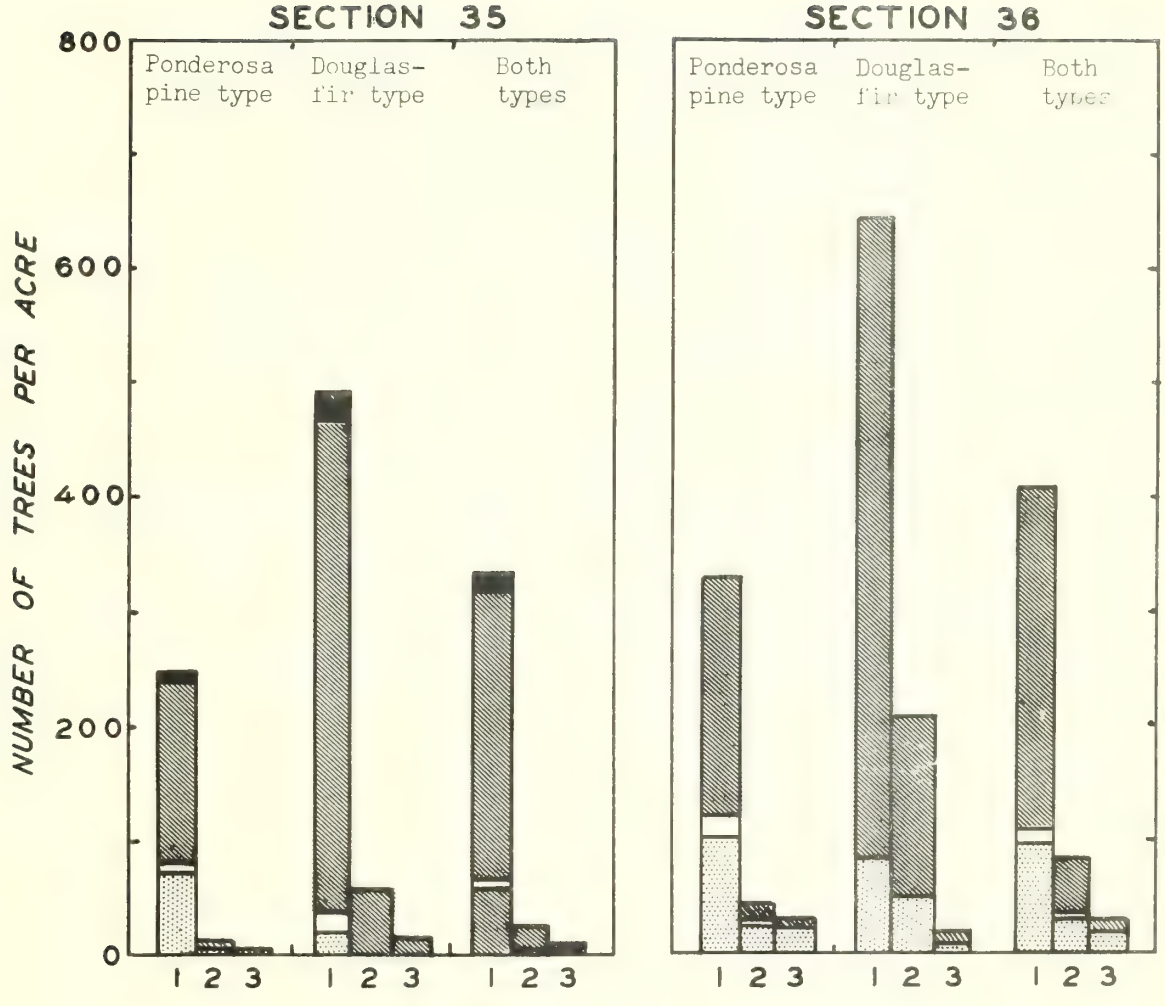


Figure 11. Reproduction of ponderosa pine and Douglas-fir within their respective types before and 7 years after logging on the Rock Flat area.

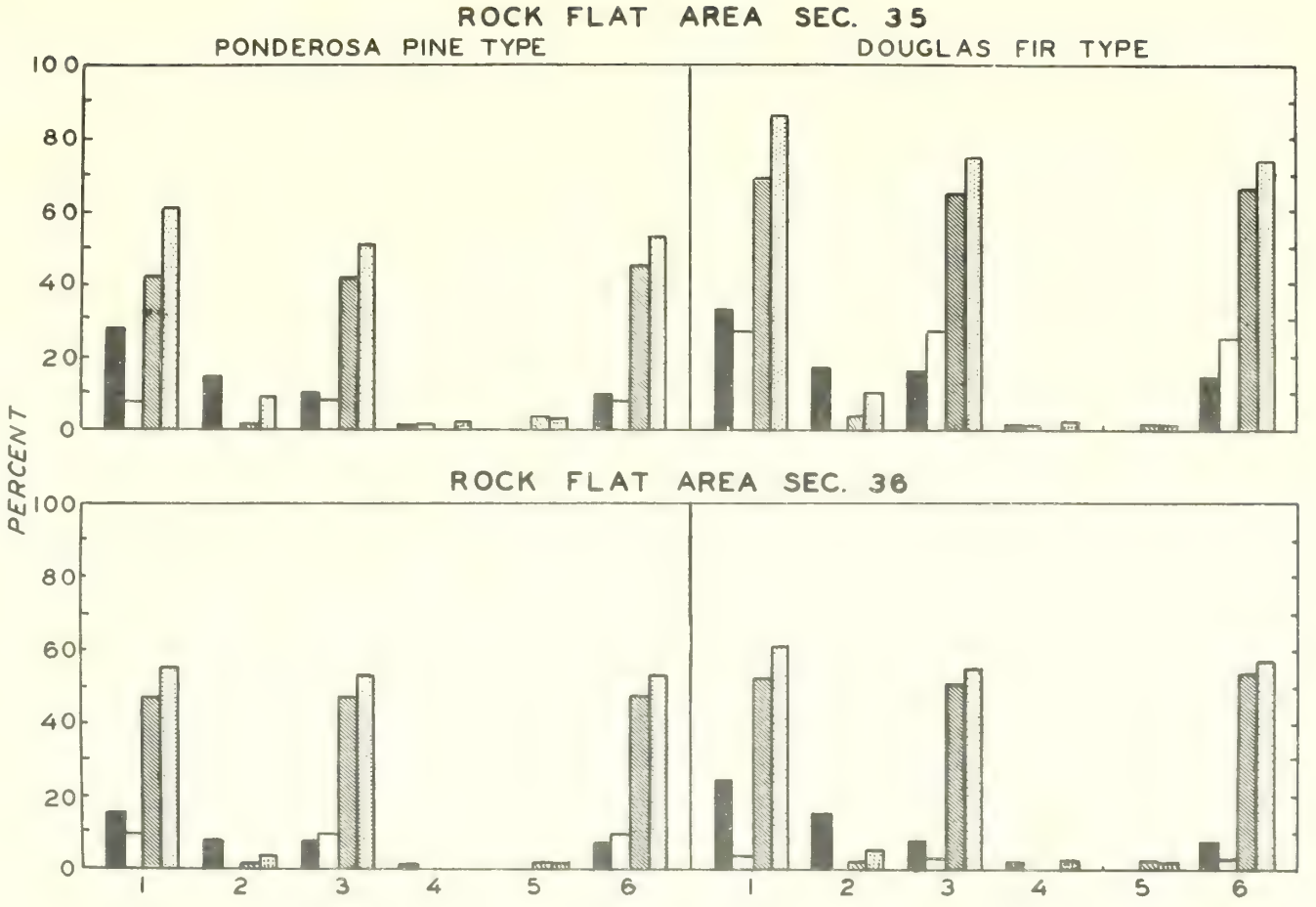


Figure 12. Gains and losses in reproduction and total stocking by percent of quadrats stocked in two forest types on the Rock Flat area.

exception of one west aspect on Rock Flat, ponderosa pine predominates on all south, west, and ridge aspects while Douglas-fir predominates on all north aspects.

In view of the time which elapsed since logging on the Lowman area (26 years) it is not surprising to find a greater amount of reproduction since cutting than on other areas. Judging from reports written before and after the logging on this area, however, there was, in the first place, good advance reproduction and, in addition, an excellent seed crop in 1906. Furthermore, it appears quite possible that subsequent good seed years occurred and these may have been followed by good growing seasons in the period since cutting.

Reproduction in relation to volume removed - The Lowman area had the least volume per acre removed (58 percent) and was cut to the highest diameter limit (20 inches d.b.h. for pine and 16 inches for fir). By contrast, the private land on Clear Creek had the greatest volume removed (98 percent) and the lowest diameter limit (10 inches d.b.h. for both species).

For comparative purposes it is unfortunate that for both types, the amount of reproduction up to 3 inches d.b.h. on private land equalled or exceeded that on national forest land on all aspects before cutting began. There is slightly more reproduction after logging on private land than on national forest land. Previous studies[7/] have shown that in selectively cut stands (reserve of 6,000 board feet per acre) there was more than twice the seedfall in virgin forests. It has also been found[8/] that there was ample reproduction up to 100 feet surrounding seed trees. Actually, then, it is likely that factors other than volume removed per acre (possibly the greater proportion of disturbed soil) explain the establishment of slightly more reproduction per acre on an area where there was actually a smaller seed source.

Comparisons before and after logging on the "cat" logged area on Pine Creek are not available but for the 15-year period since logging, on a 350 quadrat sampling of 72 acres it was found that, considering the ponderosa pine type alone with a representation of Douglas-fir, there was an over-all net decrease in numbers of reproduction (0 to 3.6 inches d.b.h.) of 4.5 percent. While the pine had shown an 11.6 percent increase, the fir had decreased 22.2 percent.

The striking amount of postlogging reproduction on the Lowman area is certainly more than coincidental and exceeds considerably the amount of prelogging reproduction. Furthermore, the bulk of it is in the

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7/ United States Forest Service. Intermountain Forest and Range Experiment Station. Annual Report 1936-37. pp. 76-77. Ogden, Utah. 1937 (Mimeographed).

8/ United States Forest Service. Intermountain Forest and Range Experiment Station. Annual Report 1935-36. p. 23. Ogden, Utah. 1936. (Mimeographed).

smallest (youngest) age class. From what records are available, heavy seed years in southern Idaho occur at about 8-year intervals. But heavy seed years do not, in themselves, insure seedling establishment; they must be followed by favorable (wet) growing seasons. Just what interval must elapse before these two phenomena coincide is unknown and unpredictable but obviously the longer the period, the greater the liklihood of coincidence.

It will be noticed also that there is a higher gain (15.2 percent in the pine type and 12.9 percent in the Douglas-fir type) in the stocking since cutting class in the Lowman area than any other.

Reduction in stocking due to type of logging - Since all study areas were logged by horses the only comparison available is with the Pine Creek sale on the Experimental Forest which was logged by tractors with "arches" and "pans." Mowat[9/] found that the percentage of area stocked by trees of all sizes was reduced by 12.4 percent to 65.4 percent by skidding, some 15 percent below what can be considered satisfactory. As can be seen from figure 4, there was more than twice the loss on the horse-logged Clear Creek private land (the highest loss of all areas) than on Government land in the ponderosa pine type. This was in spite of the fact that before logging there was greater stocking on the former than on the latter. Unfortunately direct comparisons are not available since losses due to logging and slash burning were not separable accurately when tallying in the present study was done.

Mortality - When all sizes of trees are considered, from seedlings to mature trees, it is interesting to note that the greatest mortality during and after logging occurred on private land on Clear Creek in the pine type. It is anomalous that there should be no recorded losses in the Douglas-fir type in the same area although this is doubtless due to the heavy stocking of trees less than 9.5 inches before logging. Excepting this instance, all losses in stocking were higher in the fir type than in the pine type. This trend is somewhat neutralized when reproduction from 0-3.5 inches d.b.h. only is considered, although the Clear Creek area still exhibits the greatest damage in the pine type and least in the fir type.

Size classes - For ideal distribution there should be, for each area, the same proportion of stocking for each size class. Admittedly this is one of the most difficult tasks to achieve in the managed forest and one of the main goals toward which silvicultural cuttings are aimed. Some idea of the distribution of size classes can be gained from reference to figs. 4, 8, and 12. Several striking points are evident in these figures. The Clear Creek pine type private land--which was cut heaviest--has the lowest stocking of any area in all size classes; the Lowman area--which was cut lightest--has the highest. While the fir type in Clear Creek private land is 100 percent stocked, superficially suggesting satisfactory condition, it will be seen that there is no stocking whatever in the 9.6

9/ Mowat. Damage by logging and slash disposal in Idaho ponderosa pine. Reprinted from Jour. Forestry 38(3). pp. 247-255. March, 1940.

inch d.b.h. class and up which means that while net annual increment in the area is high, the base on which this is calculated is correspondingly small, and a long period must elapse before cutting of merchantable timber can take place.

In all cases, the greatest percentage of stocked quadrats is in the 0-3.5 inch d.b.h. class; and antithetically, the least percentage of stocked quadrats is in the pole class. The best distribution in both timber types occurs in the Lowman area, the area cut longest ago and also the area with the lightest cut.

The above indicates the condition of stocking only and it is to be realized that stand volume and structure might show a more encouraging picture for the different areas.

Stocking - Stocking figures for the six areas examined vary from a minimum of 46.3 percent in the pine type on Clear Creek private land to a maximum of 100 percent in the fir type on the same area. The Lowman area showed the most satisfactory stocking on the average, being 80 percent stocked in the pine type and 88 percent stocked in the fir type. The fir type showed a higher proportion of stocking in all cases (except one) than the pine type, though in most instances the difference was not substantial. It can be seen from figures 4, 8, and 12 that the gain in stocking for all areas (for both types) is inconsequential except at Lowman, where the increase was 15 and 10 percent for the pine and fir types, respectively. On the Pine Creek area on seven 10-acre methods-of-cutting plots, considering all sizes of trees and in the ponderosa pine type, only one showed a decrease in stocking, although two others showed no change. For the seven plots considered together there was an 8 percent increase in stocking in the 15 years since logging. This area is still not satisfactorily stocked despite the increase since logging.

As can be seen from table 2 by far the greater proportion of consecutive unstocked quadrats occur in the 4 - 10 class. This means that for all areas, the greatest number of consecutive unstocked quadrats resulted in distances not greater than 2½ chains or 165 feet, an effective seeding distance. It will be noticed that on private land there are more unstocked consecutive quadrats which extend further than all other areas.

CONCLUSIONS

In view of the times when the study areas were logged (only two periods of time since logging are involved if differences of more than a year are disregarded) and considering the absence of reliable information on seed crops and favorable growing seasons, it is difficult to draw certain conclusions which might otherwise be possible. There are certain indications, however, which are sufficiently marked to justify attention.

Postlogging reproduction - Although the amount of postlogging reproduction and high degree of stocking of well-represented sizes on the Lowman area may be the result of a number of causes, it would appear

Table 2. Percentage of total quadrats on which there was no live tree growth

Area	Consecutive Quadrats		
	4-10	11-30	31-50
	Percent	Percent	Percent
Clear Creek			
Private	2.25	1.30	.23
National forest	2.39	.57	-
Lowman	1.09	.23	-
Pearsol	1.66	.10	-
Rock Flat			
Section 35	2.50	.31	-
Section 36	2.03	1.09	-

more than a coincidence that the period (26 years) since logging is largely responsible. This premise is strengthened by the fact that on all other areas, where the postlogging period is 7 - 8 years, there is a dearth of reproduction since cutting. It might be suspected that a period of 15 years would be sufficient to increase reproduction per acre and increase the stocking but the Pine Creek data do not bear this out entirely even though a heavy seed crop occurred in 1940 and was followed by the wettest growing period in 25 years. The number of seed trees left in the current system of cutting should be ample but reasonable physical and climatic conditions for the germination of seed and growth of seedlings would have to exist to insure seedling establishment. While it is probable that heavy seed crops are produced more often than at 15-year intervals, it is unlikely that favorable growing seasons are sufficiently frequent to coincide with them. It is quite possible that a medium seed crop followed by good growing conditions the following spring can outweigh the factors of fewer seed trees and average plant competition and to a lesser extent the effect of aspect.

Logging damage - Judging from the difference in stocking reduction as a result of "cat" and horse logging, and the number of trees of different sizes (1,078 per acre) destroyed in the former method, there appears to be little doubt, at least from the silvicultural standpoint, that animal power is preferable. This is not difficult to understand when these two methods of timber extraction are seen in action. That "cat" logging is more efficient from the operator's standpoint is undeniable but a compromise of horses and smaller machines or at least "D 7's" without blades would result in less damage to the valuable advance

growth. The avoidable destruction by machines of grown whether it be 4 inches high or 40 feet high and which possibly required from 15 to 100 years to reach its present size, can hardly be condoned and certainly not justified on the basis of sympathy for the operator. Apart from fire prevention, the importance of reducing logging damage to a minimum transcends all else.

Douglas-fir preponderance - There is no denying the fact that the representation of Douglas-fir reproduction and the proportion of it in relation to ponderosa pine, even in the ponderosa pine type, are impressive. By reference to figures 2, 3, 5, 6, 7, 9, 10, and 11, this fact may be appreciated more emphatically. While a majority on north, east, and perhaps creek bottoms is to be expected, the presence of it on other aspects and even in the ponderosa pine types in the amounts shown by the figures, prompts one to believe that establishment and at least early growth of this species does not present a problem. Korstian and Baker[10/] concluded that while various factors produce changes in numbers of Douglas-fir and ponderosa pine per acre from time to time the present composition of the ponderosa pine type in central Idaho is likely to persist and that Douglas-fir is not increasing significantly.

Effect of aspect on reproduction - North aspects support by far the most reproduction, largely Douglas-fir. Creek bottoms support least. Only south aspects support a preponderance of ponderosa pine in all cases. The four ridge aspects also show pine in major proportions. Generally, east aspects support more Douglas-fir than pine and west aspects, antithetically, support more ponderosa pine than Douglas-fir. On the basis of this evidence it appears advisable to favor pine on ridges and south and west slopes, and fir on north and east slopes, bearing in mind that sound silvicultural practice recognizes the wisdom of retaining a proportion of ecologically associated species where such retention does not seriously interfere with the production of the main crop.

APPLICATION OF RESULTS

There appear to be several considerations on which it might be propitious to focus attention in order that the above conclusions can be appreciated and translated into usefulness.

In southwestern Idaho it is apparent that though natural reproduction of ponderosa pine establishes itself surely, it does so very slowly, more slowly indeed than is generally appreciated. The knee-high reproduction which is seen in the forest, in all probability has taken from twice to five times its age in establishing itself, and the saplings right next to it, may have taken 30 years or more to reach their present dimensions starting from the time an opening there first appeared. Since

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10/ Korstian, C. F. and F. S. Baker. Is Douglas-fir replacing western yellow pine in central Idaho? Jour. Forestry 22:755-764. 1922.

the early establishment of reproduction after cutting is as important as high net annual increment per acre of wood volume, every possible effort should be made to secure it soon, indeed, before cutting if practical.

There are several humanly controlled procedures which can contribute to the success of ample reproduction. These are:

1. Exclusion of uncontrolled fire at all times.

2. Removal of such volumes per acre as to provide ample seed from reasonably fire-resistant trees and to discourage undesirable competition such as Ceanothus by maintaining an overstory wherever feasible.

3. Conservation of as much advance reproduction, saplings and poles, as possible by animal or modified tractor where logging "cats" are as small as are consistent with a fair, economical return in relation to skidding loads. Skid roads should be chosen before logging starts and woods crews should be "briefed" on damage caused by felling and skidding and the reasons for minimizing it. A special effort should be made to educate and interest them in the fact that the saving of remaining trees and seedlings is as important as the removal of the timber.

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A REVIEW OF UTAH'S BIG GAME, LIVESTOCK, AND RANGE RELATIONSHIP PROBLEMS

By
Research Committee
Utah Big Game, Livestock, and
Range Relationship Project

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

Ogden, Utah

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A REVIEW OF UTAH'S BIG GAME, LIVESTOCK, AND RANGE RELATIONSHIP PROBLEMS

By
Research Committee,
Utah Big Game, Livestock, and
Range Relationship Project[1]

Man through excessive livestock use has brought about widespread forage depletion of western ranges. During the past 10 to 20 years, also through man's action, large herds of big game animals have built up to occupy part of this same range. In many cases this has placed a double burden on range already depleted thus creating a great controversy between livestock operators and game enthusiasts over the equitable assignment of range. This controversy has focused attention on the urgent need for gathering facts and developing principles for management which will produce the maximum combined crop of game and livestock and at the same time restore and maintain range and watershed values.

To meet this need in Utah a cooperative organization was formed in the fall of 1946. A Research Committee actively engaged in carrying out the research program consists of a representative of each of the following agencies:

Utah State Fish and Game Commission
Utah State Agricultural College and Experiment Station
United States Fish and Wildlife Service, and
Intermountain Forest and Range Experiment Station, of the Forest Service, U. S. Department of Agriculture

Also cooperating in the project are the Bureau of Land Management and Region 4 of the United States Forest Service.

One of the first functions of the Research Committee was the preparation of this report as a basis for a coordinated research program. This report is divided into three main parts: (1) background material which should lead to a better understanding of the problems involved; (2) the cooperative research program outlining the main problems, possible methods of attack, and responsibilities of the cooperating agencies; and (3) review of important literature.

1/ Research Committee members: Odell Julander, range conservationist, Intermountain Forest and Range Experiment Station, Ogden, Utah; W. Leslie Robinette, biologist, U. S. Fish and Wildlife Service, Salt Lake City; Arthur D. Smith, associate professor of range management, Utah State Agricultural College, Logan; and D. M. Gaufin, big game supervisor, Utah State Fish and Game Department, Salt Lake City. The Committee wishes to acknowledge the assistance of J. G. Smith, range conservationist, Intermountain Station, in the preparation of much of this report.

BACKGROUND MATERIAL

Range Condition and Use

Utah's big game-livestock ranges have been subjected to overgrazing for many decades. Since about 1890 livestock have made continuous and excessive demands on available range forage. Beginning about 1930 increases in big game have contributed to range depletion on many areas.

Lands under Federal regulation as well as private lands have suffered severely from overgrazing. Grazing allotment condition in 1948 as shown by Forest Service estimates in figure 1 is an example. More than one-half of the grazing lands on national forests of Utah are recognized as livestock problem allotments where range has deteriorated because of overstocking. Of the total recognized problem area (54 percent), 41 percent is overstocked with livestock, 10 percent with both deer and livestock, and the remaining 3 percent by deer alone. Adjustments in numbers believed to be satisfactory have been made on about one-fourth of the livestock problem allotments. As shown in figure 1, most of the depleted game range has also been overgrazed by either cattle or sheep or both. The remaining 3 percent of the game problem range is inaccessible or closed to livestock and demonstrates clearly that game alone, when too numerous, can deplete a range.

Protected relics of native vegetation indicate that depletion in most of the major types has been severe. The results have been not only a decreased and inferior forage supply but serious impairment of watersheds. In mountainous areas adjacent to communities and cultivated valleys, depletion of forage has brought on flood and sedimentation problems far more serious than loss of forage. The industrialization and increasing population of Utah make even more urgent the restoration and maintenance of depleted ranges for watershed protection and forage production.

Most of Utah's range is multiple-use land. The mountainous areas are especially valuable as watersheds. Recreation is becoming increasingly important in the mountainous areas. In recent years about 2½ million visitors have used Utah national forests annually for recreation and demands for public recreational areas are increasing. Approximately 152,000 acres of usable national forest range in Utah have been closed to livestock grazing for watershed protection, recreation, and other purposes. Some communities have purchased private land and excluded grazing for watershed protection and recreation.

Wildlife of some form use practically all of Utah's range land. Deer alone use about 35,000 square miles of range. Numbers of deer hunters in Utah have increased from 5,650 in 1925 to 23,000

in 1935, to 95,073 in 1948. The trend is believed to be still upward and organized sportsmen are asking for more consideration of big game in the management of public ranges.

Ownership Patterns, Seasonal Ranges, and Management Problems

The farm-village type of settlement in Utah and subdividing of land has resulted in a pattern of small farm and ranch units. More than half of the cattle permits on the national forests of Utah are in the 1-20 size class which results in costly management practices, or more often, in neglect of management. Likewise, 65 percent of the sheep permits fall in the 1-100 and 101-300 head size class.

Utah's ranges are distinctly seasonal, only a very small part being yearlong range. Cattle move relatively short distances from summer range to winter range or winter feed lot but sheep are often trailed 100 to 200 miles between summer and winter ranges. Many bands are forced to use the same driveway resulting in an uncertain forage supply en route for all but the first bands. National forests supply chiefly summer forage. A good share of the livestock summering on national forests winter on grazing districts and depend largely on private range for spring-fall use. This is especially true for sheep.

Unfortunately, these seasonal ranges are not balanced with forage demands of livestock and game. More than half of the usable range land of Utah is winter livestock range, roughly one-fifth to one-fourth is summer range for game and livestock, and one-seventh to one-sixth is spring-fall livestock range. Summer range has, by far, the greatest grazing capacity per unit of area. Spring-fall forage is often scarce and is becoming increasingly so since in recent years, season of permitted use on both national forests and grazing districts has been shortened. This has increased length of grazing season on privately owned spring-fall ranges or on cultivated crops.

Big game seasonal ranges are still less evenly balanced than livestock ranges because game animals are more restricted in their migrations and have no source of supplemental forage from cultivated crops. In several areas of southern and western Utah, summer range is inadequate for deer but in most of the State winter range is the limiting factor.

Shortage of spring and fall livestock forage on foothill ranges and concentrations of deer and elk in winter on these same areas are the major factors responsible for the present game-livestock controversy in Utah. The facts that much of this range is privately owned and that deer and elk do considerable damage to agricultural crops in winter have heightened the controversy.

The Relationship of Land Ownership and the Deer Problem

State and many private range lands are small scattered tracts which are difficult to manage because they do not form natural grazing units and fencing is impractical. Often they are interspersed within large areas of national forest or grazing district range which adds to the problem of administering public lands. The various forms of land ownership which exist within the principal ranges of deer in Utah are shown in table 1.

Table 1. Land ownership of deer range in Utah in square miles and percent of total

Class of range	Summer range		Winter range		Total	
	Square miles	Percent	Square miles	Percent	Square miles	Percent
Bureau of Land Management	4,075	17.1	9,040	59.9	13,115	37.8
Forest Service	9,855	53.8	1,945	12.9	11,800	34.0
Private Land	4,423	22.7	2,600	17.6	7,023	20.2
State Land	693	3.7	697	4.4	1,390	4.0
Indian Service	65	0.3	584	3.5	649	1.9
Other Federal	400	2.1	199	1.3	599	1.7
Railroad	60	0.3	68	0.4	128	0.4
Total	19,571		15,133		34,704	

It is evident from these data that the Federal lands are most important from the standpoint of providing deer range, with lands under administration of the Bureau of Land Management and the Forest Service providing approximately 72 percent of the total. Further, it should be noted that while the Forest Service controls over half of the summer range, the Bureau of Land Management controls an even higher percentage of the winter range.

Private lands are third in importance comprising about one-fifth of the total area. Slightly more of the summer range is owned by private land holders than is true in the case of winter range. Winter range in private ownership and within national forests includes much of the badly depleted winter area.

These figures forcibly emphasize the need for cooperative action in regard to management of deer herds. While the responsibility for prescribing kills and fixing hunting regulations should remain with the State game organization, any action taken should be preceded by consultation and conference with the other groups which, by reason of providing deer range, have an interest in the status of game numbers.

Livestock Numbers

Since early settlement the production of range livestock has been a basic industry of Utah. From the time when gaunt cattle were driven across the plains by the Mormon pioneers in 1847, Utah's cattle industry developed rapidly. As early as 1890 there were about 360,000 cattle on Utah ranges and a maximum number of 484,000 cattle was reached in 1920. The 1947 estimates show 438,000 beef cattle. Development of the sheep industry in Utah likewise was spectacular. Stock sheep increased from 599,000 in 1880 to 2,150,000 in 1890 with a maximum number of 2,882,000 in 1901. The 1947 estimates show 1,518,000 stock sheep. Since 1890 or earlier there has been a tremendous demand for range forage in Utah.

Reliable livestock numbers by land ownership classes are not available, hence only figures from national forest ranges are given below as examples. Maximum livestock production on national forest range in Utah occurred between 1915 and 1920 with World War I pressure for greater meat production. Numbers of livestock far exceeded the forage supply. Since that time reductions in livestock grazing on national forests have been made to restore overgrazed ranges and to protect vital watersheds from accelerated erosion. During this period of livestock reductions, there was an upward trend in deer numbers as shown in figure 2 which pictures the big game and livestock use of national forest range in Utah from 1924 to 1947. However, early estimates were poor and part of the increase in big game shown is believed to be due to improved census methods. Total grazing use appears to have changed but little.

Reductions in grazing animals have on many ranges been too small and too late with consequent serious reduction in the capacity of the land to produce forage and regulate stream flow. Private and public lands both have suffered from overstocking.

Table 2 indicates the livestock and deer use on national forest (including private land within the forests), Indian Service, National Park Service, and Bureau of Land Management lands within the boundaries of the game management units shown in figure 3.

Use data for livestock on private and State lands are incomplete. This lack of information accounts, in large measure, for the apparent excess of deer use over livestock use on some units, for example at East Canyon and Coalville. On others such as in Davis County, numbers of livestock have been greatly reduced for purposes of watershed protection and recreation.

In general, a much greater proportion of the total forage is used by livestock than by deer. Whether the relationship indicated is the correct balance, or whether there should be more livestock and fewer deer, or more deer and fewer livestock is an administrative question to be settled on the basis of range-watershed condition and local economy, unit by unit. In striking the correct balance, the fact must be kept in mind that winter range limits the deer population on most units.

Table 2. Livestock and deer use on Federal grazing lands within game unit boundaries, Utah, 1946

Game unit	Animal unit months* per square mile		
	Livestock	Deer	Total
Cache	76.6	24.8	101.4
Wellsville	24.5	20.3	44.8
Avon-Mantua	71.3	17.5	88.8
Ogden River	147.5	30.7	178.2
Lost Creek	152.7	13.7	166.4
Davis County	2.0	15.8	17.8
East Canyon	3.0	21.7	24.7
Coalville	2.9	19.8	22.7
Kamas	51.1	34.4	85.5
Heber	78.6	37.6	116.2
Salt Lake	10.2	42.4	52.6
Timpanogos	48.4	54.4	102.8
Heaston	13.9	23.8	37.7
Stansbury Mountain	25.5	64.3	89.8
Vernon	58.4	32.5	90.9
Eureka	65.7	16.7	82.4
Black Fork	31.5	4.7	36.2
Ashley	42.4	9.1	51.5
Daggett	47.8	23.0	70.8
Currant Creek	48.7	14.0	62.7
Avintaquin	63.3	20.5	83.8
Spanish Fork	109.3	29.6	138.9
Nebo-Fountain Green	88.1	26.6	114.7
South Nebo	94.9	39.6	134.5
Minnie Maud	63.8	7.4	71.2
Book Cliffs	51.8	6.5	58.3
Huntington	97.6	12.7	110.3
Joe's Valley	88.2	29.1	117.3
Fairview-Mt. Pleasant	107.1	24.7	131.8
Ephraim	144.4	66.4	210.8
Twelve Mile	131.4	59.5	190.9
Muddy	115.4	24.8	140.2
Oak Creek	62.9	32.2	95.1
Fillmore	58.5	31.5	90.0
Salina	81.5	31.5	113.0
Kanosh	51.4	33.9	85.3
Monroe	54.6	38.8	93.4
Marysvale-Circleville	52.1	43.0	95.1
North Beaver	57.7	31.5	89.2
South Beaver	44.2	14.5	58.7
Antimony	48.7	26.0	74.7
Parowan-Panguitch Lake	46.0	24.3	70.3
Dixie	53.1	26.0	79.1

Table 2 continued.

Game unit	Animal unit months* per square mile		
	Livestock	Deer	Total
Kolob	26.2	14.3	40.5
East Zion	38.1	10.7	48.8
Paunsaugunt	61.8	10.2	72.0
Boulder Mountain	49.6	6.2	55.8
Fremont-Crater Lakes	88.7	18.1	106.8
Thousand Lake Mountain	41.1	25.7	66.8
Henry Mountains	65.1	8.5	73.6
San Juan	43.4	22.9	66.3
LaSal	162.4	25.5	187.9
Raft River	46.6	4.9	51.5

* One animal unit month = 1 cow for 1 month.
5 sheep or 3.5 deer = 1 cow.

History of Big Game in Utah

Early accounts of big game in Utah do not give a clear picture of abundance. However, from such records as are available numbers could not have been very large as were those of the buffalo herds on the Great Plains. The first description of Utah's range in a "natural" state is found in Father Escalante's journal of 1776. Although he and his party traveled through and along the borders of some of Utah's best present-day big game hunting grounds, he made no mention of either deer or elk, both of which he noted in southwestern Colorado.

Further accounts of big game in Utah are obtained from the diaries, letters, and journals of the "mountain men" and explorers who started to pass through the territory as early as 1820. All these uniformly describe the western part of the State as being practically devoid of game, a condition that exists today, and report that buffalo, deer, elk, and antelope were to be found only in the northern valleys.

The Mormon pioneers entered the valley of the Great Salt Lake in July 1847 and soon afterward established settlements throughout most of the State. Although the writers of the time recount the hardships and difficulties endured in obtaining enough food for survival, they seldom mention big game.

After the establishment of ranches, towns, and cities, the free and unregulated use of the ranges and unrestricted hunting soon reduced the populations of deer and elk that were originally present. By the end of the century many groups within the State were becoming concerned with the disappearance of big game. The first Utah Fish and Game Department was organized in 1894 and a few regulations were put into force. Until 1907, however, no hunting license was required and the open season on deer extended for 5 or 6 months with each hunter being permitted to take several animals. By 1908 the destruction of big game had proceeded so far that the State Legislature deemed it wise to prohibit all hunting for a period of 5 years. It was generally realized that this drastic action was necessary if complete annihilation was to be avoided.

Other legal action favorable to big game increase followed. In 1913 the "buck law" was passed to protect female deer. In 1916 the U. S. Biological Survey started predatory animal control to protect livestock. This action also favored big game increases. Between 1917 and 1923 the State Legislature established a series of large refuges totaling nearly a million acres within national forests which provided yearlong protection for big game.

Range overuse by deer in Utah was first recorded in 1930. By this time breeding herds had reached substantial sizes and phenomenal increases in deer numbers resulted. In 1933 the Board of Big Game Control (formerly Big Game Refuge Committee and Board of Elk Control) was given power to regulate deer herds on overstocked areas. Serious local overpopulations of deer and abuse of the range led to the authorization of antlerless deer hunts on certain areas in 1934 and 1935. Antlerless deer hunts were again authorized in 1938 and have continued on restricted areas throughout the State up to the present time in an effort to balance deer numbers with the forage supply.

Estimated numbers of deer increased from 18,500 in 1925 to about 200,000 in 1942. A recent consideration of census and kill records indicates a population of 300,000. It is now believed that this number prevailed in 1942 and has been kept nearly constant since then by hunter harvest. A part of this large increase in estimated numbers is due to improved census methods in recent years. Nevertheless, the trend was rapidly upward.

Big Game Grazing

The information contained in the map (figure 3) of deer management units, seasonal ranges, and problem areas is a product of the joint contributions of the field men of the Utah State Fish and Game Department, Utah State Agricultural College, U. S. Forest Service, Bureau of Land Management, and Fish and Wildlife Service. The map represents the best information on deer distribution in the State which individuals of these agencies could supply. It is fully

realized, however, that this merely represents a start and that many changes and additions will be necessary as present information is supplemented in the future. It is known, for example, that some deer are found on most of the several mountain ranges in the west central portion of the State. However, it was deemed advisable to omit these areas until more is known about deer numbers and their seasonal distribution. The field men of the various agencies are cognizant of the need for data of this nature and their observations in the future will unquestionably do much to augment our present information.

Each of the herd management units shown on the map is believed to enclose the yearlong range of a fairly distinct herd of deer. It is the intent of the Fish and Game Department to maintain deer kill and population records for these units. As additional data on the migrations of deer are obtained, however, it may be necessary to make certain boundary changes to conform with field findings.

Table 3 summarizes the areas of seasonal ranges and deer problem areas by management units as given on the map. Big game problem areas are range areas where deer and to a lesser extent elk have clearly been responsible at least in part for a depleted browse condition, or where they are doing considerable damage to crops or orchards. In some instances areas were classed as problems because the better browse species are being currently used to excess by big game, in other cases they are problem areas because the present population of big game is increasing and at the point of exceeding the carrying capacity, and in still other instances areas were considered problems because the vegetation is not responding satisfactorily even though heavy reductions have been made in the numbers of big game. Many problem areas have been at least in part cleared up during the past few years but at the same time new ones have made their appearance. Hence, constant revisions are necessary in any attempt to map problem areas.

The deer range listed on the map covers approximately 34,700 square miles or about 41 percent of the area of the State. Additional range not outlined on the map on which some deer are known to range would add another 3,000 to 4,000 square miles to the above total. The 1947 estimate of deer within the deer range shown on the map was 198,000 or 99 percent of the 200,000 deer estimated for the entire State. A later estimate placed the total population at 300,000, but the proper allocation of the additional 100,000 to the game units has not yet been considered.

The 1947 estimates are believed to be generally low. A few glaring discrepancies have already been found. For example, the 1947 estimate for Wellsville was 500, but 1,200 were actually counted in 1949. The Avon-Mantua herd was estimated at 2,500 in 1947, but around 4,000 deer were counted in 1949. Davis County

Table 3. Area of winter and summer deer ranges, area of big game problem areas, estimated numbers of deer and number of deer per square mile of seasonal range by deer management units--Utah, 1947

Management units	Summer range: Area in square miles: All	Summer range: Area in square miles: Big game problem areas	Winter range: Area in square miles: All	Winter range: Area in square miles: Big game problem area	Estimated number deer 1947	Deer per square mile: Summer range	Deer per square mile: Winter range
Cache	765	--	203	86 (42%)	7,000	9	34
Wellsville	68	--	16	--	500*	7	31
Avon-Mantua	158	--	38	34 (90%)	1,000*	6	26
Ogden River	276	--	59	4 (7%)	3,000	11	51
Lost Creek	418	--	81	31 (38%)	2,000	5	25
Davis County	86	--	22	15 (68%)	500*	6	23
East Canyon	292	--	24	--	2,000	7	83
Coalville	348	--	84	34 (40%)	2,500*	7	30
Kamas	454	--	43	23 (53%)	5,000	11	116
Heber	203	--	25	--	2,500	12	100
Salt Lake	219	--	64	38 (59%)	3,500	17	55
Timpanogos	236	--	35	27 (77%)	4,300	18	123
Heaston	162	--	126	19 (15%)	2,000	12	16
Stansbury Mountain	96	40 (42%)	128	20 (16%)	4,200	44	33
Vernon	218	10 (5%)	98	--	3,000	14	31
Eureka	81	--	124	--	1,000	12	8
Black Fork	506	--	In Wyoming	--	700	1	--
Ashley	1,217	--	483	99 (20%)	4,500	4	9
Daggett	726	100 (14%)	242	225 (93%)	6,500	9	27
Currant Creek	553	--	546	--	4,500	8	8
Avintaquin	456	4 (1%)	379	47 (12%)	5,000	11	13
Spanish Fork	689	--	180	40 (22%)	7,500	11	42
Nebo-Fountain Green	229	97 (44%)	221	34 (15%)	3,500	15	16
South Nebo	167	--	136	18 (13%)	3,500	21	26
Minnie Maud	891	--	876	--	3,800	4	4
Book Cliffs	1,648	--	952	--	5,000	3	5
Huntington	215	--	190	--	1,500	7	8
Joe's Valley	167	--	127	25 (20%)	2,500	15	20

Table 3 continued.

Management units	Summer range: Area in square miles: All	Summer range: Area in square miles: Big game problem areas	Winter range: Area in square miles: All	Winter range: Area in square miles: Big game problem area	Estimated number deer 1947	Deer per square mile: Summer range	Deer per square mile: Winter range
Fairview-Mt. Pleasant	121	--	46	4 (9%)	1,200	10	26
Ephraim	94	--	30	10 (33%)	2,400	26	80
Twelve Mile	135	9 (7%)	61	32 (52%)	3,400	25	56
Muddy	240	--	105	--	2,500	10	24
Oak Creek	144	72 (50%)	154	3 (2%)	2,800	19	18
Fillmore	231	108 (47%)	205	47 (23%)	4,000	17	20
Salina	403	25 (6%)	251	97 (39%)	6,000	15	24
Kanosh	345	29 (8%)	211	66 (31%)	5,500	16	26
Monroe	310	108 (35%)	194	44 (23%)	5,700	18	29
Marysvale-Circleville	195	32 (16%)	84	25 (30%)	3,500	18	42
North Beaver	165	58 (35%)	325	25 (8%)	4,500	27	14
South Beaver	105	22 (21%)	485	7 (1%)	2,500	24	5
Antimony	253	115 (45%)	208	112 (54%)	3,500	14	17
Parawan-Panguitch Lake	657	--	261	61 (23%)	6,500	10	25
Dixie	435	100 (23%)	884	18 (2%)	10,000	23	11
Kolob	374	--	107	--	2,000	5	19
East Zion	423	--	535	119 (22%)	3,000	7	6
Paunsaugunt	330	--	678	--	3,000	9	4
Boulder Mountain	867	7 (1%)	1,351	34 (3%)	4,000	5	3
Fremont-Crater Lakes	225	12 (5%)	153	18 (12%)	2,000	9	13
Thousand Lake Mountain	123	--	157	22 (14%)	2,100	17	13
Henry Mountains	311	--	497	--	2,000	6	4
San Juan	550	155 (28%)	1,997	122 (6%)	17,000	31	9
La Sal	292	--	379	--	5,000	17	13
Raft River	699	--	273	--	1,400*	2	5
Total or average	19,571	1,072 (5%)	15,133	1,685 (11%)	198,000	10	13

* Recent counts are much higher for these units. The 1947 estimates are believed to be low for most other units also.

were estimated at 500 in 1947; an actual count of 1,200 was made in 1949. A kill of 2,800 bucks and does from the Coalville unit was made in 1949 without substantially reducing the herd. Obviously the 1947 estimate of 2,500 deer for this unit was much too low. The Raft River winter deer herd was estimated at 1,400 in 1947 but track counts along the Utah-Idaho line in 1950 showed at least 6,000 deer moving into Utah from Idaho in addition to the local deer. It is possible that other unit estimates are likewise too low. These examples show that constant revisions in deer estimates and in problem allotment appraisals are necessary.

On the basis of 198,000 deer on 34,700 square miles, there are on the average 112 acres per deer. It would seem that this acreage would be more than adequate for meeting the forage needs of a deer throughout the year. However, there are three factors which have created range problems: (1) Much of the range is of very low carrying capacity, this being especially true of much of the winter range; (2) there is an uneven distribution of deer throughout the available range with excessive concentrations in some areas and sparse populations in others; and (3) much of the deer range is fully or overly stocked with livestock. Also it might be restated that the encroachment of city limits, ranches, and farm lands into the normal deer range has likewise created many special problems.

The game problem areas which have attracted the most attention are located on the winter ranges. The winter range problem areas make up only 11 percent of the entire winter range, but the perpetuation of the forage supply on this segment of winter range is essential to the welfare of many thousand deer and several hundred elk. A large number of elk and deer are forced to spend about 5 months each year on a restricted strip of range at the base of the steep mountain slopes. The amount of forage available on these restricted winter range areas often determines the numbers of big game that can be maintained.

It should be pointed out, however, that not all big game problem areas are confined to the winter range. About 5 percent of the summer game range is classed as summer game problem area. On some units, particularly the San Juan unit in the southeastern part of the State, the summer range is more restricted than the winter range. In addition the summer ranges are already fully or overly stocked with livestock.

The numbers of deer and elk will have to be reduced by hunting on the problem areas, but on other areas which are presently understocked increases can possibly be permitted. One of the chief aims of management is to effect an equitable distribution of big game which conforms with the forage supply. When this aim is accomplished, the maximum numbers of animals will be produced for hunting on a long-time basis.

Hunter Numbers and Success

The numbers of hunters increased tremendously in the past several years. If we at present have approached the maximum numbers of deer which we can expect to maintain in Utah, any increase in hunter pressure will be reflected in lower success ratios, and even though we may increase our deer herds beyond the present level, this point of diminishing game for the hunters seeking it is a condition that must be expected. Figure 4 shows the number of hunters afield and the number of deer killed in the past 23 years. Success ratio is high with over 50 percent of the hunters killing bucks in recent years. This places Utah as one of the top states in the nation as a deer hunting ground. This high success is partially due to easy hunting on overstocked range.

As deer numbers on concentration areas level off to balance the forage supply, the easy harvesting of deer will be over. However, with good management which provides for stable soil and a sustained yield of forage for grazing animals, Utah's deer ranges should provide good hunting indefinitely.

PROBLEMS AND PROGRAM

Major Problems

The problems in determining big game-livestock range relationships and of developing principles and concepts as a basis for management are many and complex. The main questions to be answered by research are as follows:

1. What is the nature and extent of competition for forage between big game and livestock, and what are the limitations for maximum sustained yield production of both on multiple-use ranges?

2. To what degree can important game forage species be utilized and insure sustained forage yield on ranges in satisfactory condition, or recovery on deteriorated ranges?

3. What are the indicators of range condition and trend that can be used as guides in administration of game-livestock ranges?

4. How can grazing capacity of range be determined for game and for combined use of game and livestock?

5. What are the effects of big game on watershed values?

6. How can game numbers be determined with reasonable accuracy?

7. What are the seasonal and permanent migrations of big game?

8. What annual production for hunter harvest can be expected from game herds?

9. What are the factors affecting big game productivity and how can these factors best be controlled by management?

10. What are the social and economic values involved in game-livestock production?

1. Nature and extent of competition

Competition implies a contest between the two classes of animals for the same forage. This being the case competition is confined to that part of range used by both game and livestock and to certain desirable species, the supply of which is inadequate for both.

Demands of both stockmen and sportsmen on a limited range resource has resulted in much controversy regarding competition of big game and livestock. Especially is this true where large numbers of game occur on private range where owners have a business investment and livelihood at stake and on valuable watersheds where public interests require adjustments in numbers of grazing animals.

To determine range competition, research is needed on preferences and seasonal use of forage and on grazing patterns of big game and livestock.

Determining the similarities and differences in forage preferences of game and livestock is necessary to ascertain the kinds of forage for which they are likely to compete. In addition seasonal forage use must be known because plants differ in palatability at different seasons and time of grazing varies with class of animal. For example, on the Fishlake National Forest lupine may be used only in fall by both sheep and deer. If both animals graze a lupine area in fall and the supply is limited, there would be direct competition. If the area is used by sheep only in spring or early summer there may be no competition at all for lupine. Such examples are numerous.

Distribution of livestock and big game on mountain range is often very uneven. Game as well as livestock prefer certain areas for such reasons as presence of desirable forage or favorable topography. The extent of overlap in distribution of game and livestock is, therefore, one of the factors which determines competition.

Some information on forage preferences of game and livestock is available from different parts of the West. Much of the older information on species palatability is based on use of forage under heavy stocking. On this basis plants were often much overrated. Few data are available on preferences based on the more recent concepts of moderate stocking. Our present information of grazing patterns is based almost entirely on general observations.

Where serious overstocking of both big game and livestock occur, competition for forage is obvious. However, the results of such overstocking on range and game herds are not fully appreciated. We know little about competition on areas with moderate stocking or with different intensities of game and livestock use. Range competition varies greatly with kind of animals involved, character of the range, extent of overstocking, extent of range depletion, and seasonal use. The problem is how to determine the nature and extent of competition, evaluate the factors involved, and develop concepts as a basis for balanced use of range by game and livestock.

Several methods of studying game and livestock competition might be used employing large pastures, small paddocks, captive deer in pens, fenced exclosures, stomach content analyses, and studies on the open range.

Large pastures give the advantage of controlled numbers of both game and livestock with a minimum restriction on activities of captive game. Numerous other studies which require knowledge of definite numbers could also be made in large pastures, such as proper sex ratio and census methods. The chief disadvantages are the high cost and the fact that studies would be concentrated in a relatively small spot and might not have wide application.

Small paddocks have the advantage of low cost, definite control of numbers of game and livestock, and portability. Their chief disadvantage is the small area enclosed which permits only a few animals to be grazed and either restricts the activities of game or necessitates the use of tame animals. Also, the period of use is short compared to that on open range, although this may be an advantage in determining seasonal forage preferences.

Feeding of captive deer in pens permits accurate measurements of forage consumed and frequent weighing of animals which should give reliable data on forage requirements. Forage preferences can be studied with any combination of species supplied. Nutritional studies of important game forage can also be studied with captive deer. Other detailed studies not possible on open range, such as relationship between forage intake and stomach content for evaluating reliability of stomach content analysis, is possible with captive deer. On the other hand, the confinement of wild animals under unnatural conditions might cause them to react differently

than on the open range. Numbers of animals would necessarily be restricted because of the difficulty and high cost of collecting native forage.

Big game and livestock exclosures which furnish total protection or protection from one class of animal and use by another give definite information on forage preferences and ecological changes in plant cover as a result of differential use. However, they supply only a very limited sample of range. Also, big game use inside livestock exclosures may be different than on the open area grazed in common with livestock and it is often difficult to clearly differentiate use by the two classes of animals.

Stomach content analysis is useful in supplying qualitative data on forage preferences. It is especially valuable in indicating forage preferences on open range during spring when plants are making rapid growth and in fall when leaves are falling--periods when utilization of plants on the ground is difficult to estimate or measure. This method may not be reliable for quantitative data since certain species disintegrate in the stomach faster or are not retained as long as others.

The chief advantages of open range studies are: (1) natural conditions prevail which present problems as they must be dealt with in management; (2) larger areas are involved which furnish a more adequate sample of range; and (3) the low cost. However, animals cannot be controlled as would be desired and game numbers are seldom definitely known. Areas grazed by game alone and by combined game and livestock are available although rate of stocking is seldom as would be desired. Moreover, exclusive livestock grazing on the type of range needing study is practically impossible to find on open range.

All methods have their advantages and shortcomings. For this reason various methods are being used.

At Utah State Agricultural College captive deer are being fed native forage for forage preference and nutritional value and determination. Paddocks and small pastures are being used to determine deer and sheep forage preferences and competition.

The Intermountain Forest and Range Experiment Station is conducting studies on open range supplemented by game-livestock exclosures and areas temporarily fenced for reseeding. Volume weights by species in pounds per acre present and used by deer and livestock are estimated on line-plot transects. Utilization estimates are being recorded throughout the year on exclusive deer range to determine forage preferences and seasonal forage use by deer. Stomach content analyses are made as opportunity affords to supplement field observations.

For determining grazing patterns the survey method supplemented by aerial photographs is being used to study deer and cattle distribution on Oak Creek range and deer and sheep distribution on Monroe Mountain range.

Since the cooperative project was started in the fall of 1946, most of the effort of the Intermountain Station and much of the time of the College, in cooperation with the Utah State Fish and Game Department, has been devoted to the problem of competition. Although much progress has been made and certain phases of study are nearing completion, this problem will receive high priority until studies are well rounded out.

2. Proper use of game forage

The ultimate aim of good range management is good range condition. Inasmuch as the condition of a range as a unit is determined by the condition of its components, proper use of vegetal species is closely related to range condition. Proper use is the degree of use which allows the more important species to maintain density and vigor, to insure soil stability and optimum forage on range in good condition, and to provide for recuperation leading to optimum conditions on deteriorated range. Proper use of a forage species involves more than resistance to grazing, which is the degree of use a plant can stand year after year and maintain its vigor and forage productivity. The ability of a plant to reproduce and to contribute litter toward soil protection must also be considered.

Ranges are not grazed uniformly from area to area because of variations in such factors as topography and distance to water. Grazing animals exhibit forage preferences, specific and seasonal. It was this lack of grazing uniformity that initiated the concepts of "key areas" and "key species." The selection of "key species" is a problem in itself. Preference value, abundance, and ecological status must therefore be taken into account. Obviously, the importance of a species may change with each vegetational association in which it occurs.

At what intensity of grazing of the "key species" does range condition begin to trend downward, upward, or remain static? This information is a basic tool without which the range administrator is seriously handicapped.

The resistance of a plant to grazing depends upon intensity of grazing, length of time of grazing, site condition, season of removal, persistence of grazing, growth conditions during any year, growth form and reproductive powers of the species.

We have some information on the grazing resistance of certain grasses, cliffrose, aspen, bitterbrush, red-stem ceanothus, serviceberry, honeysuckle, rose, true mountainmahogany, snowberry, and big sagebrush. The studies made on these species were conducted at various places in the western range area under specific edaphic and climatic influences. We need to know how these species react to grazing under the varied ecological influences that prevail on the ranges with which we are concerned and how and when seasonal growth is made. We need similar information with respect to other deer browse and forb species such as curlleaf mountainmahogany, oak, chokecherry, elderberry, penstemon, Indian paintbrush, lupine, aster, Ligusticum, meadowrue, geranium, and others.

This information could be obtained from clipping studies conducted within areas receiving total grazing protection; from open range studies on areas subject to varied grazing intensity; from pasture studies wherein grazing intensity would be subject to more rigid control; or from various combinations of the above. Clipping studies provide excellent grazing control from the standpoint of volume of material removed, but they present the problem of simulating natural grazing activity (method of removal). Then, too, browse plants which have received total grazing protection for a period of years seem to exhibit different physiological processes than plants subjected to grazing, i.e., more of their energy is diverted into short spur and flower production than into shoot growth with a resultant alteration of growth form. A more natural approach to the problem can be obtained from open range studies which permit investigation of all plants of a given species on an area and also of the community as a whole. Open range studies, however, may require the establishment of widely separated study units in order to obtain the required degrees of grazing pressure and even then complications might arise from the complete lack of grazing control. Pasture studies would provide more rapid and accurate manipulation of grazing populations; they would also be more limited in scope and very costly to establish.

To date no phase of the project investigations has been pointed specifically at the problem of proper use although some data already obtained, such as tagged-twig measurements, may be helpful in arriving at conclusions.

The proposed procedure for investigating this problem will involve both clipping and open range techniques. The trends resulting from different degrees of use will be followed by measuring volume of forage produced and establishment of new plants. Weight estimates (Ocular Estimate by Plot, Pechanec and Pickford, 1937), utilization determinations (measured and estimated), and photographs will be used.

Initial emphasis will be placed on browse because it provides the bulk of winter forage for game and it is the winter ranges that are generally inadequate.

Limitations inherent in the clipping studies will be somewhat compensated by open range studies and vice versa. If we could accomplish further control by means of a pasture, that would be ideal, but whether this would be justified in light of the high cost and areal limitation is questionable.

Studies on utilization standards are to be started in 1950 and will be given high priority by the Intermountain Forest and Range Experiment Station.

3. Game range condition and trend

Range condition is generally considered a relative state of range health compared to a standard or optimum condition based on the potentialities of the site. This standard should fulfill two requirements: first, soil stability should be insured, and secondly, the most desirable forage within the capability of the site should be provided.

Since game and livestock differ somewhat in forage preferences, satisfactory condition and trend of range may differ and the standard condition established might differ. For example, a climax grass type might be considered excellent range for cattle and any material change in cover toward a browse type would be classed as downward trend. However, a change to browse might be desirable for deer provided soil could be kept stabilized. On common use range a compromise between the two might be the objective. Consideration of this should be given in the artificial revegetation program on game-livestock range.

In Utah, as elsewhere in the West, there are understocked game ranges, ranges with varying degrees and length of periods of overstocking, ranges overstocked by both game and livestock, ranges overstocked with only game or only livestock, and deteriorated range where excessive stocking of game has been at least partially corrected by controlled hunting.

There is often sharp disagreement between stockmen, sportsmen, and management agencies on condition and trend of game range. This greatly hampers efforts now being made to balance grazing animals with forage supply. There is need for clarifying the status and limitations of criteria of game range condition and trend now in use.

Some gross guides often used are entirely unreliable. The public and some administrators may clamor for more deer on ranges already overstocked on the basis that deer are only a fraction of their former numbers, when in reality forage supply has gone downhill faster than deer numbers and further reductions are needed. Unsuccessful hunters used to hunting on overpopulated range, may lament ruined hunting grounds when actually deer from that herd

may starve when winter comes. Sportsmen hunting on summer or intermediate range in fair condition may think the deer herd should be increased, not realizing that a serious shortage of winter forage is the limiting factor.

Indicators now known are often misused because of lack of appreciation of their limitations and true values. Highlining of cedar and tall shrubs and hedging of palatable shrubs are often used to indicate problem areas where reductions are needed. When such indicators are readily apparent, serious damage has already occurred before the trouble is recognized. In some cases knowledge is lacking regarding the better species and what constitutes moderate use. Moderate use of aspen, around 50 to 65 percent, is often used as a basis for stocking deer on summer range. Because, as recent research in Utah has shown, many plants are preferred to a greater degree than aspen, moderate use of aspen by deer might be an indicator of overstocking rather than of proper stocking on many ranges.

More precise and true indicators of range condition are needed for classifying game ranges for remedial action. Likewise, indicators which will aid in detecting at an early stage upward or downward trends are needed to judge results of the management program.

Principles and concepts of range condition and trend have been formulated in recent years. Indicators have been worked out for livestock range in a few major types in the West including the subalpine range in central Utah. No work, other than general observations, has been done to date on condition and trend of game range. However, the principles worked out for livestock range will apply to game range and provide a working basis of concepts and methods.

To determine criteria for game range condition and trend, the first step is to set standards with which to compare other conditions. Ideal conditions for game range are not known. Soil stabilization, where a balance between vegetation and soil is maintained, is a prime requirement, but other standards may be difficult to determine. Information already available from forage preference studies will give some background as to the forage that would be desirable. Further concepts of the desired and potential optimum conditions can be gained by examining soil and vegetation of range that has not been overgrazed and by piecing together evidence from parts of grazed range in differing degrees of depletion and relating these to conditions and normal processes observed on undisturbed range.

By comparing the standard with ranges in various stages of depletion as a result of overuse by different game species, combinations of game species, and combinations of game and livestock, it should be possible to determine specific things relating to soil and vegetation which indicate the relative condition of the range and the class or classes of animals responsible for those conditions.

In determining indicators of game range trend it will be necessary to make observations, measurements, and photographs of soil and vegetation over a period of time on ranges with various degrees of stocking--including light, moderate, and heavy stocking on areas of depleted range. Areas where game numbers have been sharply reduced, areas building up to peak populations and those where game herds have had continuous but inadequate reductions would be desirable for range trend studies.

Research should enable us to: (1) formulate indicators now known for use in management of game ranges; (2) correct misinterpretations where these exist with known indicators; and (3) discover new indicators.

Studies on indicators of condition and trend will be started in 1950 and will be given high priority by the Intermountain Forest and Range Experiment Station.

4. Grazing capacity of game range

Grazing capacity of most game ranges involves the ability of range to support big game in addition to livestock while at the same time providing adequate watershed protection. On private range, livestock use is the main objective with game secondary. Some public range is closed to livestock and game grazing is secondary only to watershed protection. However, on the majority of public range land an attempt is made to secure maximum sustained use by both game and livestock.

In any cooperative management plan it is desirable to know grazing capacity for both game and livestock in terms of actual numbers of animals. For game management plans we need to develop methods whereby we can determine for a given range the optimum numbers of game that should be grazed and how to adjust grazing capacity estimates for game to allow for livestock use and vice versa.

For determining grazing capacity for livestock no method has replaced the practice of actual records of livestock use and their effect on the range. Supplements such as range surveys and different kinds of study plots have furnished basic data and have proved helpful. The problem is yet far from solved on many ranges. Very little work has been directed to methods of determining grazing capacity for game, although the need has been recognized and general knowledge has been used in adjusting livestock grazing to allow for game use.

Studies now in progress on forage preferences and grazing patterns, census methods, and herd productivity, and studies soon to be started on utilization standards and condition and trend, should yield data upon which to base grazing capacity of game range.

Three general methods of determining grazing capacity for game seem possible:

A. Pasture or paddock studies with known numbers of animals. Advantages and limitations of this method have been discussed under competition studies on page 15.

B. Where game numbers can be determined accurately, actual use records on properly grazed range or, where properly grazed range is not available, use records coupled with utilization studies, might be used. Determining utilization of forage and actual game numbers present are two of the greatest difficulties in arriving at carrying capacity for game, particularly deer, with any degree of accuracy. The use of the pellet group count to determine deer-days of use, supplemented with estimates of forage volume and utilization, may overcome this difficulty on some ranges. The pellet group method also has limitations since accurate counts are impossible in some types with dense vegetation.

C. On types where it is impossible to count game or pellet groups, a method relating forage utilization and length of season grazed with total forage available and total length of grazing season might prove usable. With accurate kill records correlated with forage utilization over a period of years, the number of deer which could be harvested on a sustained yield basis could be determined.

Work on grazing capacity in pasture and paddock studies is in progress at the Utah State Agricultural College in connection with forage preference and forage requirement studies. Because determination of grazing capacity on open range required other basic data, work by the Forest Service on this phase of study will be only incidental for the present.

5. Watershed values and big game

Game, as well as livestock, influence erosion and streamflow through their influence on vegetation and soil. Changes brought about by big game and livestock differ since their forage preferences and grazing habits are different. Overstocking of deer on winter range from which livestock have been excluded sometimes results in change from shrub to perennial grass type. On other areas where livestock have depleted seed stock of grasses the change may be from a desirable mixture of shrubs to a shrub type of lower value or even to an annual cover type. For example, on the Kamas deer winter range, bitterbrush, the mountainmahoganies, and sagebrush are being killed on deer concentration areas and wheatgrass is replacing them. Is wheatgrass a better watershed cover than browse or a mixture of grass and browse? On deer-sheep range in Manning Creek below the Fishlake National Forest boundary, bitterbrush has been destroyed by sheep and deer, perennial grasses have

been practically eliminated by sheep, and sagebrush is being replaced by rabbitbrush due to excessive deer use. What are the effects of such cover changes in their initial and successive stages?

Deer concentrate on south and west exposures of winter range in early spring when the soil is wet and loose in search of the first green growth. Elk likewise concentrate on localized areas when the ground is wet and apparently cause considerable soil disturbance. Although such areas are usually limited in size they may constitute a serious sedimentation problem.

No work has been done to date on the effects of big game on watersheds. Much information available from studies on effect of livestock grazing would apply to game grazing. However, soil and cover changes brought about by big game differ so greatly from those induced by livestock that they constitute a distinct problem for research. Solution of this problem is important in the management of big game on watersheds.

That this problem overlaps condition and trend studies is realized since both are concerned with soil and vegetative changes. However, since studies of watershed values would differ as to location and detailed methods it is desirable to make this a separate study. Attention will be given to this problem as time and funds permit.

6. Determining game numbers

One of the first tasks facing the big game administrator and possibly the most challenging is the determination of the approximate numbers of animals which he is managing. It is seldom possible to make a complete enumeration such as is possible with domestic livestock. Therefore, partial or sample counts or other indirect methods are necessary to approximate big game populations. Perhaps the most common census method is an intensive census of small representative areas with the results applied to larger areas. It is much like a timber cruise in which a small percent of the timber is measured and the total volume of timber on the area calculated from the sample cruise. Strip counts of deer, deer drives on sample areas, "spot" counts etc., are all variations of the same method. The results from sample cruises are usually accurate enough to indicate trends for management purposes where the terrain and deer distribution are fairly uniform.

An enumeration of signs is frequently used as a means of ascertaining big game numbers. Track counts of migrating animals have been made where there is a constriction across the migration route. Feasibility of the method is usually contingent upon whether a road runs across the migration route which permits old tracks to be obliterated after a daily count of tracks. Pellet group counts afford

another means of censusing big game. Information which must be available for application of this method is a count of pellet groups on sample units of the range, the period of time during which they were dropped, and the defecation rate of the big game species. This method appears to be feasible where the winter and summer range of the big game species is fairly distinct. Pellet group counts can be made on the winter range and are readily distinguished from those of the previous winter. The period of time which the herd spent on the area can be determined from field observations as to when they move onto and off the winter range.

Numbers of big game can frequently be calculated by means of ratios. For example, if a number of animals are trapped, tagged, and released and the total kill during the following hunt can be determined, total population can be approximated as follows:

$$\frac{\text{Total deer tagged}}{\text{Tagged deer killed}} = \frac{\text{Total population}}{\text{Total deer killed}}$$

The same method can be applied to a situation wherein a number of deer are trapped, marked conspicuously, and released. Soon after release a count is made and the following ratios obtained:

$$\frac{\text{Total deer marked}}{\text{Marked deer seen}} = \frac{\text{Total population}}{\text{Total deer seen}}$$

Changes registered in the ratios between age and sex classes because of disproportionate kills or losses through hunting or seasonal mortality likewise afford a method of censusing. This method is contingent upon field classifications of live animals by sex and age classes both before and after the period of disproportionate mortality in the sex or age classes. Also, an accurate sample of the animals which died or were killed must be obtained by sex and age classes.

Under certain conditions complete counts of game herds are possible. This is especially true for elk and antelope where herds are concentrated on small areas or where they are found out in the open. The airplane has proved to be very effective in counting these two species.

Some wildlife managers take the view that it is not necessary to know the populations of big game herds. They reason that yearly trend data of herd numbers correlated with kill data and observations of range forage conditions and utilization are all the information required for proper herd management. This may be true for individually managed herds. However, if the results of research from studies of sample herds or of managed herds are to have widespread application, it becomes necessary that we have some knowledge of total big game numbers. Net increase and various mortality percentages must be determined from a common base, that is, total herd numbers. It is also

becoming increasingly more important that we have data on total numbers of big game in any permanent management plan in order that range use be allotted between big game and livestock.

Although methods discussed above have been worked out in various parts of the nation they all have their limitations and shortcomings. The job for research is to determine the most accurate and practical census methods for use under the various conditions of the Intermountain region. The following methods are now being studied by the Fish and Wildlife Service:

A. Winter reconnaissance method--to be used annually on two areas in Utah and one in Nevada.

B. Airplane census--as time and funds permit.

C. Pellet group count method--to be applied annually on two areas in Utah.

D. Sex ratio method--to be applied annually on two Utah areas and one in Nevada.

E. Lincoln index method--as time and funds permit.

F. Strip census method on summer range--as time permits on two areas in Utah and one in Nevada.

Items C and D are being given high priority.

7. Seasonal and permanent migrations of big game

The big game manager not only must have some concept of the numbers of animals he is managing but he also needs to know something of their seasonal and range movements. The need for this information is especially pressing when the administrative agencies wish to reduce game numbers through hunting on a problem area on the winter range. Deer and elk are normally on their summer range at the time of the annual fall hunt. Hence, it is desirable and important to know where deer from problem winter range areas are at the time of the hunting season. Seasonal movements of big game can be followed by close observations during the migration period or through a marking and tagging program of the animals while they are on the winter range. Returns from hunters who have killed tagged animals or field observations of marked deer serve to supplement general observations of herd movements.

It appears from observations and studies which have already been made that big game species have a "homing" instinct in that they usually return to the same general ranges year after year. Deer especially are so persistent in this trait that many instances have been noted where large numbers of deer have died of malnutrition during the winter when an abundance of readily available forage

existed on nearby ranges not more than 3 or 4 miles distant. Tagging studies and field observations have further revealed that the seasonal and range movements are more restricted than believed by many people. A seasonal movement of 20 to 30 miles is about the maximum for most big game in Utah. However, deer wintering in Daggett County in the northeastern portion of the State are believed to travel 50 to 60 miles or possibly more from the summer range of the high Uinta Mountains to the west. Tagging studies made at Logan, Utah, showed that essentially all tagged deer which were killed during the hunting season were taken within the Logan Canyon drainage. There is considerable evidence, however, elsewhere in the State that many deer wintering on the west side of the mountain ranges summer on the east side. Most of the winter deer concentration areas are found on the foothill slopes on the west side of the mountain ranges. It would appear, therefore, that many of the deer move over the divides to the east side of the mountain ranges during the summer.

A rather interesting movement of deer is evident in the Raft River Mountain region in the northwestern part of the State. There are only an estimated 500 deer in this area during the summer and yet during the 1947 hunting season an estimated 754 bucks were killed in this region. If this number represents half of the bucks there would still have to be a surviving population of at least 4,000 deer which spend the winter in the area. From observations of employees of the Utah State Fish and Game Department it appears that most of these deer summer in Idaho and that the fall movement into Utah is initiated by hunting activities in Idaho where the deer season opens a few days prior to the season in Utah.

The Utah State Fish and Game Commission has set up a Federal aid project for the purpose of determining summer range boundaries for deer herds in the State. Work is to be started where overpopulations occur on the winter range and little information exists regarding their whereabouts during the hunting season. It is proposed that a number of deer on these problem winter ranges be tagged in the hope that returns will help solve some of the deer migration riddles.

Studies on movements of deer in relation to snow depths and temperatures will be made at Ephraim where snow and weather records are taken. Observations will also be made in connection with census methods study. Range movements of deer will be studied by earmarking and tagging fawns at Oak Creek and Ephraim Canyon.

The Fish and Wildlife Service and Utah State Agricultural College in conjunction with the Utah State Fish and Game Department are now engaged in studies mentioned above and expect to continue work along this line.

8. Productivity of game herds

The percent of a game herd that can be harvested annually without decreasing the base or breeding stock is commonly known as net

increase. Knowledge of this value for each game herd is especially useful to the manager. Net increase is not a set value for any one species nor is it necessarily the same for any one game herd from year to year. However, if these values can be determined for certain herds under a known set of conditions, then the values can be adjusted upward or downward to correspond to changing conditions. Average net increase percentages which have been derived after several years of continuous study are of considerable value in management. The percent net increase is necessarily dependent upon various factors which can be controlled to some degree by management. For deer the net change may vary from a low of minus 50 percent to a high of plus 60 to 70 percent. Negative values are usually restricted to herds which are forced to subsist on depleted ranges during severe winters. An annual net increase of about 70 percent was recorded for a small herd of white-tailed deer in Michigan for a 6-year period.

The Colorado Game and Fish Department believes that mule deer herds in their State make about a 33 percent net increase. Utah uses the more conservative value of 25 percent in predicting herd increment. This value was substantiated in part by a study of the Fishlake herd which showed an average of 27 percent for the 3-year period, 1940-1942. From present information it appears that the net increase for most deer herds may fall within the range of 20 to 35 percent.

The reproductive potential of antelope is much the same as that of deer so that, other conditions being equal, the net increment could be expected to approximate that of deer. However, small antelope herds present in the west desert of Utah have failed to increase for years. The cause for this static condition is unknown but a State Pittman-Robertson project is under way at present to investigate the reasons.

The net increase for elk can reasonably be expected to fall below that for deer or antelope. Also, cow elk are not sexually mature until they are a year older than deer or antelope. The increment rate for elk normally is believed to range from 15 to 25 percent. Small herds under ideal conditions have been known to make phenomenal increases of 40 percent or more, but this is probably never attained by large herds under western range conditions.

Much needs to be done in the way of productivity studies of specific game herds to determine the potential increases and losses to which they are subjected. Records of legal kill combined with census data on one Nevada and three Utah deer units are being collected and will be continued over a period of years to determine net increase. Such studies when correlated with studies of factors affecting net increase should supply valuable data for application to other game herds.

9. Factors affecting big game productivity

Productivity is defined in the dictionary as the power or capacity of yielding or bringing forth. As applied to a deer herd it means more specifically the capacity for producing fawns. Productivity may be divided into two classes, potential productivity and net increase. Potential productivity means the numbers of animals produced by a herd when no losses occur. This value has more meaning when expressed as a percentage of the base or breeding herd numbers. The does of mule deer rarely produce young until they are 2 years old, and usually but one offspring is produced at the first fawning. Thereafter, twins appear to predominate with an occasional triplet occurring. Very old does are believed to be much like domestic animals in that their reproductive rate is reduced below that of the prime-aged group.

Oftentimes proper herd management can do much to raise the net increase of herds and after all it is the number of animals which survive to be harvested by hunters or added to the breeding herd that actually counts. Forage supply perhaps has the greatest single influence upon net increase of any of the factors which affect survival. Physical conditions of the animals at the time of the rutting season may have a decided bearing upon the conception rate. Availability of essential minerals and a plentiful supply of nutritious, palatable forage are essentials for top physical condition. Numbers and survival of newborn fawns are unquestionably tied in closely with nutrition and physical condition of the does. Does in good physical condition undoubtedly produce more milk for their offspring than those in poor condition. Such a factor alone could result in higher fawn survival on good ranges.

The sex ratio in the breeding herd has a very decided effect upon productivity. The wider the sex ratio following the hunt the greater the percent of increase providing there are enough bucks to breed the does. Close control of the larger predators is likewise important if an optimum herd net increase is to be attained. Strict law enforcement is another factor in increasing net increase.

Pregnancy data have shown that mule deer does may have an average of 1.2 to 1.8 fetuses per doe of breeding age. Should all of these fawns live and no other losses occur in the herds, the potential productivity would probably be somewhere between 40 and 90 percent. From this high potential the net change registered by a herd at the end of the year may be all the way from a negative value to a positive one of 70 percent. From the number of fetuses carried by the does in a herd must be deducted all losses sustained by the herd during the year except those through legal hunting.

This wide disparity between potential productivity and net increase values in deer herds suggests that there may be great possibilities of increasing production through better game management.

We need to determine more definitely the causes of deer losses and how they might be prevented. For this purpose the following studies are being made by the Fish and Wildlife Service with the State Fish and Game Department and Utah State Agricultural College cooperating:

A. Pregnancy studies of deer throughout Utah to determine net increase.

B. Winter mortality studies by the survey method and over-winter changes in age classes.

C. Summer mortality studies employing differences in total loss and winter and hunting losses and possibly by new methods to be developed.

D. Mortality by predators by comparing net increase on areas with and without predator control. Studies of deer-mountain lion relationships are now under way at Oak Creek in Utah and Duck Creek in Nevada. Studies of deer-coyote relationships will be made as time permits.

E. A fawn tagging program is under way to study differences in fawn drop and survival for hunter harvest.

10. Social and economic factors

The solution of problems arising from combined use of range lands by big game and domestic livestock cannot be found in a study of the animals nor of the range alone. Each of these resources has economic and social value which must be appraised and evaluated. Undoubtedly the presence of game reduces the capacity of ranges for livestock in some degree. Similarly, some loss of forage for deer may accompany livestock grazing. Whether the competition be great or small, administrative decisions respecting either game or livestock have implications which are answerable finally only if the effects of these decisions upon society are considered.

What is the relative importance of game and livestock on the range and what would be the values involved if game were reduced in favor of livestock or vice versa? It is not possible to answer this simply on the basis of dollars and cents. Social factors which cannot readily be appraised enter to complicate analyses. Few accurate data are available from which conclusions can be drawn. It will be necessary to compile statistics of social and economic character and devise equivalents by which unlike values may be equated before rational decisions can be made. Solution of these problems can be achieved only when basic information on other phases of the research program becomes vailable.

The Research Program

Based on information contained earlier in this report, it is evident that deer are by far the most important big game in Utah needing study. Elk are important on several areas and should be included in the study as time and funds permit. With one very productive antelope herd in the State, and an ambitious antelope planting program under way, it is likely that studies of this species should be included in the future.

Problems upon which facts are especially needed are:

The determination of competition between deer and livestock as a basis for a sound approach to this controversial problem.

Development of criteria for judging range condition and trend and determination of utilization standards of game forage and grazing capacity as a basis for managing big game range.

The determination of reliable census methods and productivity of big game as a basis for manipulating numbers on a sustained yield basis.

Studies of deer migrations are needed on some areas to determine proper hunting season and special hunts on problem areas.

The effect of big game on watersheds is in need of investigation, especially in view of proposed river basin developments. Research should be started on this problem as soon as time and funds permit.

Facts on social and economic values involved in game-livestock production are needed as a basis for administrative decision on the question of "how many livestock and how many big game animals" on Utah's overcrowded ranges. Research should be started on this problem as soon as conditions permit.

In the selection of study areas a search has been made to find natural game herd units with representative vegetal cover and suitable livestock use where kill records could be checked closely. The same intensity of stocking has also been sought in selecting areas for different studies. These qualities, so important when animal and range phases of study are conducted together, have been impossible to find in any one area. Compromises have been made and desirable features sacrificed in order to carry on as much as possible of the animal and range phases of study together. The following areas have been selected for study to date:

1. Monroe Mountain Deer-Sheep Unit--for deer food habit studies and deer-sheep food habit relationship studies. This is a natural herd unit heavily stocked with deer. Half of it is grazed by sheep and deer and half by deer only. This is typical of much range in south-central Utah.

2. Oak Creek Deer-Cattle Unit--for deer herd studies and deer-cattle food habit relationship studies. This is a natural herd unit heavily grazed by deer and cattle. It is well suited for deer herd studies but is not so typical of cattle range because of its steepness and predominance of shrub type. It is a summer problem area for deer--differing from the majority of deer ranges--but it is representative of several areas in this category. The winter range although hard hit in spots is reasonably satisfactory taking all factors into consideration.

3. Ephraim Deer Herd Unit--for deer herd studies and for limited deer-livestock food habit relationship studies. This area is reasonably satisfactory for deer herd studies but the grazing use is such that it can be used only to a limited extent for deer-livestock food habit studies.

4. Kamas Deer-Livestock Unit--for deer winter range studies and deer-cattle and possibly deer-sheep food habit studies on livestock spring-fall range. This range is heavily stocked with both deer and livestock and some areas grazed by deer only. It has a considerable amount of the very important shrubs such as true mountain-mahogany, curlleaf mountainmahogany, bitterbrush, and serviceberry along with sage and oak. While hard hit, the highly palatable shrubs have not been killed here as they have on many ranges. The area is not suitable for year round deer herd studies because of unlimited and undefined summer range but is very good for winter range studies. It is typical of the northern half of the State in that summer range is plentiful and winter range extremely limited.

5. Parawan Deer Unit (and others to be selected)--for study of seasonal migration and range of important deer herds.

6. Controlled studies of forage requirement and nutritive value will be located in the vicinity of Logan.

Other studies such as deer-cattle food habit studies and range condition and trend will be conducted on several areas throughout the State wherever suitable facilities and conditions can be located. Also, studies such as mountain lion food habits, deer pregnancy studies and others will be State-wide. The Hardware Ranch Game Range Unit is being considered for a possible study area. Other areas may be selected for certain phases of study as the work progresses.

The various phases of work will be carried on simultaneously by the different agencies and will be correlated into one research program as shown in the following outline.

An Outline of the Project Research Program

An asterisk indicates major responsibility or center of activity. Letters indicate the agencies participating in the various studies: FS = Forest Service, FG = State Fish and Game, AC = Utah State Agricultural College, FWL = Fish and Wildlife Service, and RU = Wildlife Research Unit.

1. Animal phase

   a. Census methods

      (1) Winter reconnaissance - (FWL*, RU)

      (2) Airplane counts - (FWL*)

      (3) Pellet group counts - (FWL*, AC*, RU)

         (a) Penned deer and paddock-grazed deer

         (b) Application to open range

      (4) Sex ratio - (FWL*, RU)

      (5) Lincoln index - (FWL*, FG*)

      (6) Strip census - (FWL*, RU)

   b. Productivity studies

      (1) Legal kill and population trend - (FWL*, FG*)

      (2) Herd composition studies - (FWL*, RU)

      (3) Pregnancy studies - (FWL*, FG)

      (4) Mortality studies - (FWL*, FG)

         (a) Crippling loss

         (b) Winter loss

         (c) Summer loss

         (d) Early fawn loss

         (e) Predation

c. Miscellaneous studies

(1) Weight and measurement studies - (FWL*, RU*, FG*)

(2) Migration studies (FG*, FWL)

(3) State-wide big game inventory (FG*, FWL)

(4) Life history studies (FWL*, FG*)

2. Range phase

a. Big game-livestock food habit studies

(1) Open range studies (FS*)

(a) Deer food habit studies

(b) Deer-sheep food habit relationships

(1) Forage competition

(2) Grazing patterns and overlap in feed grounds

(c) Deer-cattle food habit relationships

(1) Forage competition

(2) Grazing patterns and overlap in feed grounds

(2) Feeding native forage to confined animals (AC*, FG*)

(a) Winter feeding of deer

(1) Varied diets

(2) Restricted diets

(b) Summer feeding of deer and sheep

(3) Paddock grazing studies (AC*, FG*)

(a) Deer

(b) Livestock

(4) Miscellaneous studies

(a) Utilization standards of game forage (FS*)

(b) Utilization techniques (AC*, FS)

(1) Modification of Cassady's unit-weight method

(2) Other methods

(c) Nutritive value of important forage plants used by game (AC*, FG*)

(1) Chemical analyses

(2) Digestion trials

(d) Analyses of forage habit approaches (AC*, FG*)

(1) Study of reliability of species-minutes analyses

(2) Study of stomach analyses in relation to food intake

b. Indicators of game-livestock range condition and trend (FS*)

(1) Game range

(2) Deer-cattle range

(3) Deer-sheep range

c. Carrying capacity studies

(1) Fenced paddocks with known numbers (AC*)

(2) Open range (FS*)

3. Social and economic studies (AC*)

a. Social and economic factors involved in game and livestock production

4. Evaluation of results and revision of research program

REVIEW OF LITERATURE

This review of literature was made primarily to give the authors a knowledge of work already accomplished on the problems of big game-livestock relationships and on related studies which would contribute to this subject. It is not intended to be exhaustive.

A more complete list of references on wildlife up to 1938 was compiled by Renner et al (1938) and the history, condition, and a program for improvement of the western range has been reviewed in a report by the U. S. Forest Service (1936).

Forage Survey

Inventory of the forage resource has been given most of the attention by those engaged in range research and administration.

The point-observation-plot (square-foot-density) method of conducting range surveys was developed by Stewart and Hutchings (1936). This method and the reconnaissance method were described in some detail by Pickford (1940) who also discussed the objectives, values, extent, and application of range surveys. In an effort to standardize results, a method for conducting game range surveys was recommended by Schwan and Swift (1941). Dasmann (1945) criticized the reconnaissance and square-foot-density methods of making range surveys because they fail to take into account forage volume and he proposed another method involving forage weight, allowable cropping factor, and preference rating. He also (1948) reviewed the various range survey methods and discussed their application to deer range management. Standing (1933) was one of the first to try and replace density with volume as a measure of productivity. Smith (1944) studied the reliability of forage density estimates and found significant inter-and intra-daily variation in the same individual, among different men, and among different species. In addition, he found little relation between average density estimates and actual forage yield as determined by clipping. Culley, Campbell, and Canfield (1933) have discussed the values and limitations of clipped quadrats. Humphrey (1940) pointed out the difference in value of a forage-acre on different ranges and suggested the use of more than one forage-acre-requirement in range surveys. In Texas, Buechner (1944) employed three sizes of plots in a vegetational study; in a 5-acre plot, species were listed for presence, in a ¼-acre plot crown coverage of shrubby species was estimated, and in a 100 square meter plot herbaceous cover was estimated. Key species and key areas were discussed by Mitchell (1941) and the key species concept was used by Rasmussen (1939) as one of four forage study methods applied to the same area. Hanson and Ball (1928) applied Raunkiaer's Law of Frequence as a tool in studying the effects of grazing systems upon vegetation.

Hanson (1934), after a comparison of various methods of sampling the prairie forage of North Dakota, concluded that a large number of small samples is better than a small number of large samples. The process of sampling vegetation on sagebrush-grass range was presented in considerable detail by Pechanec and Stewart (1940) and Pechanec (1941). Pechanec (1937) also described a weight-estimate method for the determination of range production. Carhart and Means (1941) used the weight-estimate method in appraising range for deer carrying capacity. Wilm, Costello, and Klipple (1944) reported on a double-sampling method of estimating forage yield and pointed out that for

experimental work it was good and "in large-scale extensive surveys, the clipping of all plots may prove to be at least as efficient as any short-cut method."

Grazing capacity

If the range manager can determine with a fair degree of accuracy the number of animals that his range will properly support, he will have advanced a long step in the satisfactory performance of his job.

Stoddart (1935) proposed a method of determining the grazing capacity of wheatgrass range that involved the counting of wheatgrass stalks on meter-square quadrats to obtain utilization; this has been criticized by Pechanec (1936). In Colorado, Douglas (1938) concluded that a concentration of 75 acres per deer approached saturation, but that if the summer and winter range were better balanced, the yearlong requirement could be lowered to 50 acres. Swift (1946) reported an average of 47 acres per deer for the national forest lands of Utah. The great disparity in volume of seasonal ranges for game was pointed out as far back as 1897 by the superintendent of Yellowstone National Park as reported by Olson (1938). Cahalane (1943) further described this inequality. After a study of foods available to deer and those eaten by deer, Hill (1946) concluded that grazing capacity calculations should give little if any weight to plants of low palatability and no weight to the unpalatable ones. Rasmussen (1939) investigated the grazing capacity of an area using four methods, one involving density and another, weight. The capacity estimated by the weight method was more than twice that estimated by the density method. Mann (1933) listed his requirements for the determination of grazing capacity; Kidder (1946) proposed a determination that converts forage production to pounds of total digestible nutrients. The use of range condition classes calculated as percentages of a predetermined condition was advanced by Humphrey (1947). The approximate number of animals grazing the range, the degree of use of the key forage species, and the resistance of the key species to grazing were combined by the U. S. Forest Service (1945) in estimating grazing capacity.

Utilization

The rapid and accurate determination of utilization is complicated by a multitude of factors and yet it is probably the most important single thing that governs proper range management.

Hanson (1929) investigated the belief that grazing was more intense near a fence or similar obstruction and concluded that such a belief was unfounded on small range pastures of 100-200 acres. Clipping techniques were reported on by Cassady (1941), Young and Payne (1948), and Johnson (1941). The first was used to determine forage use by sheep, the others to determine utilization standards for

particular species. Cook, et al. (1948), using a modification of Cassady's clipping technique, found sheep to be highly selective in their diet when forage was abundant, and much less so when forage was not abundant. The study of browse utilization has received considerable attention from a number of authors. Forsling and Storm (1929) reported in detail how to study browse use on cattle range in Utah, and Nelson (1930) described two methods of mapping shrubs. Julander (1937), Aldous (1945), the Interstate Deer Herd Committee (1947), and others have investigated the measurement of twigs before and after grazing as an indication of utilization. Hormay (1943 a and b) described a simple method of estimating grazing use of bitterbrush and concluded that about 60 percent was proper use. Methods of classifying ranges with respect to degree of stocking were advanced by Aldous (1944) and Hunter (1945). Humphrey (1949) discussed several methods of making utilization surveys and proposed one involving range condition classes. The measurement of stubble height as a means of determining utilization of grass was discussed in some detail by Canfield (1941, 1944), Reid and Pickford (1941), and Clark (1945). In the latter two pieces of literature, and in a third by Pechanec and Pickford (1937), various methods of determining utilization are compared and similar conclusions drawn in each, i.e., that the ocular-estimate-by-plot method as developed at the U. S. Sheep Experiment Station in 1933 deserves much consideration over the others. Swift (1941) listed some criteria for determining proper forage utilization on big game winter ranges. McCain (1948) described the use of pellet group counts for measuring intensity of deer use on the winter range of the Interstate Deer Herd, California.

Food Habits

Food habits of big game herbivores are influenced by so many factors and vary so widely from one locality to another that findings of particular studies may have local application only. Although the relative part played by forbs, grass, and browse in the yearlong diet of game animals may be constant, categorical values cannot be given because of variations in forage present and season of use.

The literature contains many references pertaining to the food habits of elk, Pickford (1943), Gaffney (1941), Roberts (1930), Rush (1932), Schwartz and Mitchell (1945), Shoemaker (1930), Smith (1930), Young and Robinette (1939), De Nio (1938 a and b), West (1941), and others. Most of these authors concur in the belief that elk are primarily grazing animals, feeding mainly on grasses and other herbaceous plants whenever this type of forage is available.

A very intensive food habits study of the blacktail deer was made by Cowan (1945) in which he observed that they avoided the seed heads of grasses and sedges and that thorns on plants have a real protection value against deer browsing. Dixon (1934) pointed out the reluctance of mule deer to take seed or flower heads of grasses, but Robinson (1937) found that the usual mule deer habit of grazing

mature grasses is to take the heads only. Hill and Harris (1943) do not agree that thorns have a real protective value against deer browsing and they cite the fact that, in their investigations in the Black Hills, rose was one of the principal food plants of both whitetail and mule deer. Hahn (1945) reported that the Texas whitetail preferred grass and forbs in the spring and that oak leaves and acorns made up the bulk of stomach material collected throughout the rest of the year. Murie (1933) and Norris (1943) pointed out some of the dangers involved in the determination of food habits from stomach analyses.

Some of the more detailed studies of mule deer food habits have been presented by Nichol (1938), Carhart and Coutts (1941), Carhart (1944), Dixon (1928 and 1934), Doman and Rasmussen (1944), Edwards (1942), Rasmussen (1941), Doman (1943 a and b), and Robinson (1931 and 1937). These authors are generally agreed that browse makes up the principal part of the yearly diet and that grass is taken in rather large amounts at certain times, mainly in the spring. However, Rasmussen (1941) concluded from his observations on the Kaibab that grass constitutes less than 10 percent of the food eaten even when preferred foods are scarce. Robinson (1931) noted that after grass dries it does not appear to be palatable to deer, and yet the report of the Interstate Deer Herd Study, Interstate Deer Herd Committee (1947) indicated that almost a third of the winter diet of deer consisted of dry grass.

Couey (1946) found that the autumn diet of Montana antelope consisted mainly of browse, with sage, snowberry, and snakeweed rating high. In a snow-trailing investigation in Oklahoma, Rouse (1941) revealed that antelope took a predominance of shrublike perennials or half-shrubs in December. Buechner (1947), after an intensive study of antelope in west Texas, concluded that, throughout the year, forbs made up more of the total consumption than browse and grass combined. Ferrel and Leach (1950), on the basis of 56 stomach samples from California antelope, reported that browse and forbs together made up more than 97 percent of the total early and late summer diets with browse dominant by a wide margin in early summer and forbs dominant by a slight margin in late summer. Common sagebrush appears to be the staple food during the time of year in which the samples were taken.

Boone (1938) investigated means of improving deer food supply by transplanting nursery-raised shrubs and by clear-cutting aspen stands to produce sprouts. In both cases, the cost was found to be prohibitive.

Competition

The question of conflict for forage between big game and livestock is one which has been discussed with a great deal of heat and very little light. Shantz (1938) presented a somewhat general

treatment of the subject in which he pointed out that preferences of livestock and deer for grasses differ and that deer readily take other plants which cattle do not care for. Johnson (1944) felt that there was much overlapping in the feeding habits of deer and sheep and of elk and cattle. Schwan (1945) drew similar conclusions and further indicated that the extent of deer-sheep summer conflict was very likely great. He added that elk normally prefer a more varied diet than cattle and stressed the need for more accurate information. A very thorough investigation of the Oregon-California deer herd reported on by Fischer et al., (1944) and Interstate Deer Herd Committee (1947) revealed serious competition between deer and cattle for bitterbrush. The former authors also reported on the similarity of deer and sheep diets in the spring, but minimized competition because of the abundance of the species used by both. Stoddart and Rasmussen (1945 a and b) pointed out that local competition may be very serious, but that the general situation is probably overemphasized. They presented a method of calculating direct competition by making use of the differences in both area used and food habits. The conflict between sheep and elk for summer range forage was reported by Pickford (1943) and Pickford and Reid (1943) to be direct and severe.

Knipe (1944) concluded that the similar food preferences of sheep and antelope produce considerable conflict, but that this is not as marked with cattle. Buechner (1947) advanced similar conclusions and offered a means of computing competition based on the assumption that both animals eat the same species.

Cliff (1939) pointed out that the winter diets of deer and elk were very similar and that serious competition could develop between these game animals. Mitchell (1950) indicated that elk and deer were strongly competitive and that one elk is equivalent to four deer on the basis of forage intake requirement.

Nutrition and chemical analysis

The chemical analysis of deer foods growing on different sites was reported on by Einarsen (1946) who found that plants growing in old burns or logged openings had higher protein content than those found in the closed canopies of mature timber. He also confirmed the summer to winter decline in protein content of forage which had been pointed out by Hormay (1943a). Hellmers (1940) found a general downward trend in the nutritive value of browse from winter to spring. Reynolds and Sampson (1943) investigated the composition of the vigorous, highly palatable sprout growth produced by cutting or burning chaparral and reported a water, mineral, and crude protein content twice as great as found in the older growth. Aldous (1945), working with bitterbrush, found a higher concentration of nutrients in the tip ends and leaves than in the rest of the stem. De Nio (1938a) determined that the nutritive value of Douglas-fir and lodgepole pine

compared favorably with Idaho fescue, a high ranking palatable grass. Forbs et al. (1941), and Maynard et al. (1935), have performed digestion experiments on whitetail deer. Few native forages were included, common livestock feeds composing the bulk of the feeds tested. Atwood (1948) has tested the forage value of some species important in the diet of the whitetail deer by noting the weight changes in rats and suggests this method as a possible short-cut means of testing deer forages.

Irruptions

Most of the States where deer herds are present have experienced rapid build-ups in deer population which exceeded the available forage supply. The outbreak of the Kaibab deer herd in Arizona is an outstanding early example of such an irruption and might have served as an example of how not to manage a deer herd. This lesson was not heeded and one by one the States learned this costly lesson by experience. Leopold et al., (1947) have traced the growth of deer herd irruptions throughout the country. They have likewise discussed the reasons for irruptions and the necessary requisites for proper management.

Census

The more palatable plants taken by big game must be checked closely and at the first sign of overuse the numbers of animals must be stabilized. The only effective management tool to accomplish this is the annual removal of the surplus males and females. The administrator in recommending removals needs to know how many deer he has and their rate of increase as well as number of hunters and their expected success.

Numerous census methods have been employed throughout the country with varying degrees of success. Rasmussen and Doman (1943) have given a very fine treatise on census methods, especially as applied to mule deer. The authors conclude that one of the more promising is the winter count or reconnaissance method which is used throughout much of the West. It is employed during late winter when the winter snows have forced the deer down to foothill slopes where there is only a limited amount of cover. Under these conditions when the deer are concentrated, a rather effective count can be made by men on horseback or afoot. Only a partial count can be made but trend data are obtained by recording numbers seen on identical areas from year to year. Trend data together with deer removal figures give the manager some valuable data for managing his herds. Airplane censusing of deer during the winter months has been rather successful in some parts of the country, especially in the middle west where a hardwood cover and level terrain prevail (Morse, 1946; Saugstad, 1942). In Utah the airplane census has been rather disappointing although in some areas with a small amount of juniper-pinyon pine cover encouraging results have been obtained. Hunter (1945a), feels that airplane

censusing gives reliable trend data and is especially feasible for inaccessible areas which are difficult to reach afoot or on horseback.

The strip census method has reportedly been successful in determining numbers of white-tailed deer in the Central States, the South, and the East, (Ruff, 1939; Erickson, 1940; Krefting and Fletcher, 1941; Hahn, 1945; and others). The method was given a thorough trial in central Utah (Rasmussen and Doman, 1943) and the results were so variable as to render the method valueless, at least for conditions encountered in Utah. Deer drives on measured areas have been used successfully, especially in the Lake States and parts of the East when enough manpower was available (U. S. Forest Service, 1935; Hosley, 1936; Adams, 1938). The results from small representative areas were in these cases applied to larger areas. The method is costly and impractical in mountainous terrain. In addition the distribution of deer is so uneven in the mountainous deer habitat of Utah that results from small areas could not safely be applied to large areas.

Returns on tagged deer killed by hunters permit a calculation of numbers through a relationship of the percentage of tagged animals killed to the total kill. Lincoln (1930) used this method on waterfowl, and Olsen (1938) and Rasmussen and Doman (1943) have used it to a limited extent on deer herds. There are several objections to the method as applied to big game herds. Data on natural losses of tagged animals are usually unavailable and complete returns on tagged animals killed by the hunters are likewise usually unavailable. It is also difficult and expensive to tag the large numbers of animals which would be necessary under this method.

Kelker (1940, 1944, 1945) has developed a number of mathematical equations for determining deer herd numbers. The principle involved is that differential kills in the sex and age classes during the hunt results in changes in the sex ratio and age class ratios. Field classifications of live deer must be made before and after the hunting season from which to derive the necessary ratios. In addition, sex and age classifications of deer killed during the hunt must be obtained. These data permit calculations of the herd populations. This census method has been used with varied success in Utah.

Pellet group counts (Bennett et al. 1940; Rasmussen and Doman, 1943) are of some merit in censusing deer. Their data show the rate of pellet group defecation to be about 12.5 groups per deer per day for mule deer. For areas where the deer are forced onto restricted as well as rather definitely defined ranges as during the winter, the method appears to be feasible as well as accurate. Another advantage of this method is that animal day's use can be determined. On much of the western range there is a rather distinct separation between the winter and summer ranges of deer. Thus, pellet groups can be counted on plots on the winter range at the time the deer are

leaving in the spring and the current winter's pellets can be distinguished from those of the previous winter. The area of the winter range must be determined and the period of time spent on the area by the herd. With the above information, deer numbers can be determined for an area.

Daily track counts across migration routes of deer have given some very good results (Wright and Swift, 1942). The Utah State Fish and Game Department has also made effective use of this method. Rasmussen and Doman (1943) have listed forage utilization as a census method. Weight estimates of available forage must be determined on the winter census area before and immediately after the deer leave. The difference in the two weight estimates would thus be correlated with the period the deer were on the area and the daily consumption rate of the average deer. Forage intake per hundred pounds liveweight has been determined from feeding experiments of deer by a number of workers (Doman and Rasmussen, 1944; Nichol, 1938; Davenport, 1939; and others).

Productivity

If the manager wishes to determine the net increase of a big game herd, he needs estimates of herd number, annual removal by hunters, and trend data to indicate what percent increase or decrease has occurred from year to year with known hunter removals. Kelker (1945, 1947) discusses the theoretical and mathematical phases of productivity and net increase in big game herds. Cheatum and Morton (1946) have done some commendable work in New York State concerning regional differences in the productivity of whitetail deer. They found a marked difference in the pregnancy rate of does in two different geographical regions of the State. The most logical explanation of this they conceded was a difference in nutritional planes.

Leopold (1933) has developed tables showing potential increases for big game species. He shows the numbers of animals which will accrue each year for a number of years starting with one animal of each sex for varying rates of offspring per female and for different ages of sexual maturity for the females. Natural herd losses would have to be subtracted from the potential increase as given in the tables in order to obtain the net increase. Some data are obtainable on big game herd increases for herds that have originated from planted stock. If the original number of animals in the plant are known as well as the end number after a certain number of years, prior to legal hunting removals, the net increase can be determined through use of the compound interest formula. Thus, the George Preserve herd of 160 resulted from an original plant of two bucks and four does 6 years previously (Hickie, 1937). The net annual rate of increase was 65 percent by assuming an even sex ratio at the start. From this potential high the net increase may vary to the other extreme so that there may actually be a decrease during the course of a year. This is particularly true on overstocked ranges where heavy mortality from

malnutrition occurs. Thus, the Kaibab herd, which increased at an estimated rate of 19 percent annually until the peak population was reached in 1924, decreased at the same rate for the next few years (Rasmussen, 1941). Rasmussen and Doman (1947) estimate that mule deer herds in Utah can normally produce an annual net increase of 25 percent.

Mortality

In order to better interpret the reasons for varying degrees of net increase, studies should be made of age classes in big game herds as well as mortality from various factors. Winter mortality may be especially severe and probably is greater than any other seasonal loss except possibly early fawn loss in summer and hunting removal in the fall. Taylor and Hahn (1947) report malnutrition losses of whitetail deer in Texas as high as 50-60 percent of the herd in 1 year's time. Doman and Rasmussen (1944) found a herd loss of 22 percent occurring during the winter of 1942-43 for the Logan-Green Canyon herd in Utah. Obviously such losses reduce the numbers of harvestable deer. For this reason the manager or researcher should have means of accurately estimating winter mortality. Cliff (1939) reported about a 50 percent loss of a deer herd during the winter of 1931-32 in the John Day region of Oregon. Colorado and Minnesota have estimated that losses from malnutrition in some years for certain herds have greatly exceeded the hunter take from the same herds.

Crippling losses from gunshot wounds also reduce the numbers of harvestable deer. Sanders (1939) and DeBoer (1947) report crippling losses in Wisconsin as great as 45-68 percent of the legal removal. Costley (1948) found crippling losses of 72 percent of the legal kill in southern Utah on an area open only to buck hunting as against 33 percent where both sexes were hunted. Hunter (1945b) states that 15 percent of the numbers of deer and elk taken legally during the hunts are left dead from gunshot wounds on the range.

Predators exert considerable pressure upon big game herds at times and their exact effect is difficult to measure. Horn (1941), Young and Goldman (1946), Dixon (1934), and others have accepted the deer-a-week rate of kill for the mountain lion. Actual trailing studies of individual lions in the winter have shown a much higher rate of kill than this. Sperry, as reported by Young and Goldman (1946), Dixon (1934), Hibben (1937), and others have found deer to be predominating item in the cougar's diet. Because of their greater numbers, coyotes possibly kill more deer than mountain lions. Horn (1941) found that coyote control in California resulted in a material increase in fawn deer survival. He also found that, contrary to the belief of many, coyotes were taking normal healthy deer rather than the weak. Murie (1940) concluded from Yellowstone studies that most of the big game taken by the coyote was in the form of carrion or weakened animals. There appear to be two schools of thought

on this matter. It seems possible that what the coyote takes may in a large part be governed by what is available. If weakened and dead big game animals are available, or if there is a high population of rabbits or other buffer species, depredations upon healthy big game animals would probably be reduced to a minimum. Bobcats have not been considered an important predator of mule deer, but in the East, Marston (1942) and Matson (1948) found that bobcats were not only capable of killing normal healthy deer in the winter time but were taking substantial numbers.

Parasites and diseases

The researcher and administrator should know something of the parasites of big game and their influence upon the well-being of big game herds. Herman (1945), Cowan (1946), Whitlock (1939), and many others have written some very fine papers on the parasites and diseases of deer. In general, their conclusions have been that parasites are only of secondary importance in mortality of big game animals. Parasites are usually more prevalent in herds which have already been weakened by malnutrition. Diseases likewise seem to become of importance in herds which are already in poor physical condition because of poor range conditions. A notable exception to this was the outbreak of hoof-and-mouth disease among deer in the Modoc region of California in the 1920's which had been contracted by deer from infected livestock, Keane (1926). In controlling the outbreak it was necessary to poison 22,214 deer on an area of 1,000 square miles.

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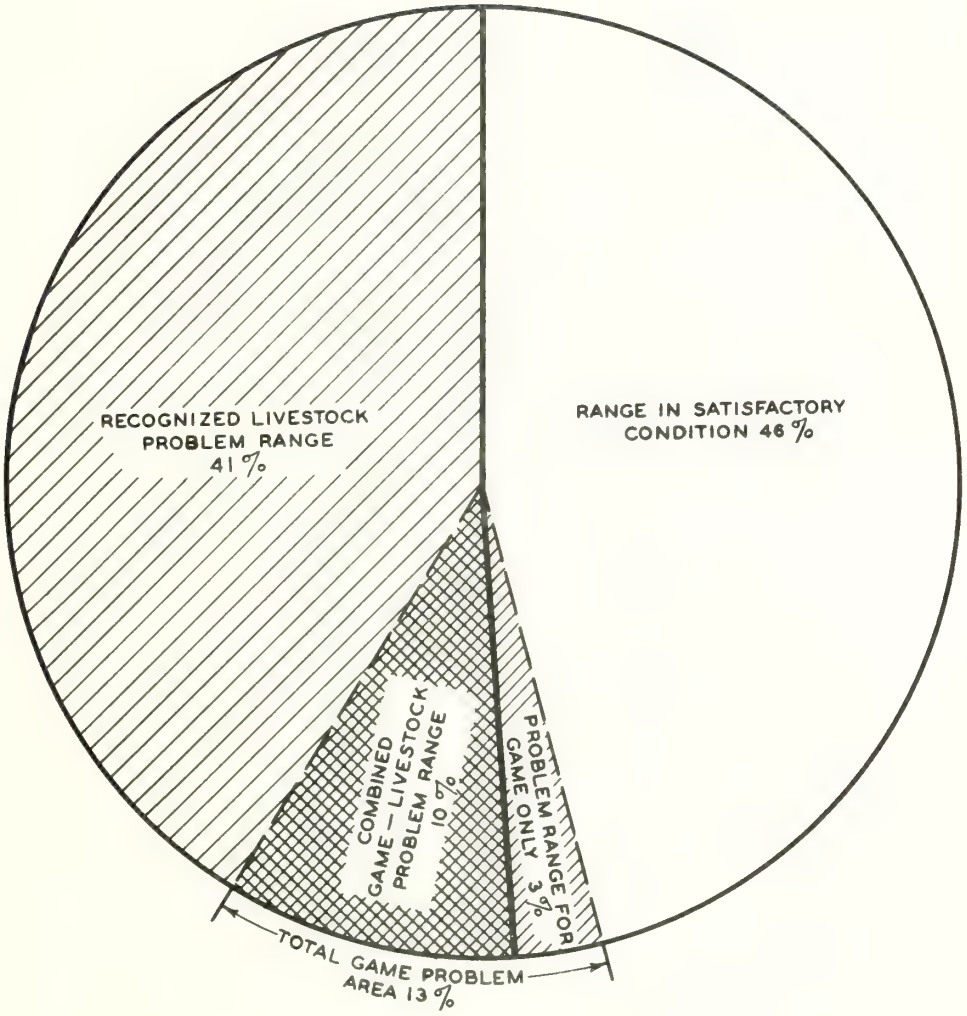

Figure 1. Range conditions on national forests of Utah, 1948. Over half of national forest range is in recognized livestock problem allotments. Most of the game problem range is overgrazed by livestock as well as big game.

(AGRICULTURE - OGDEN)

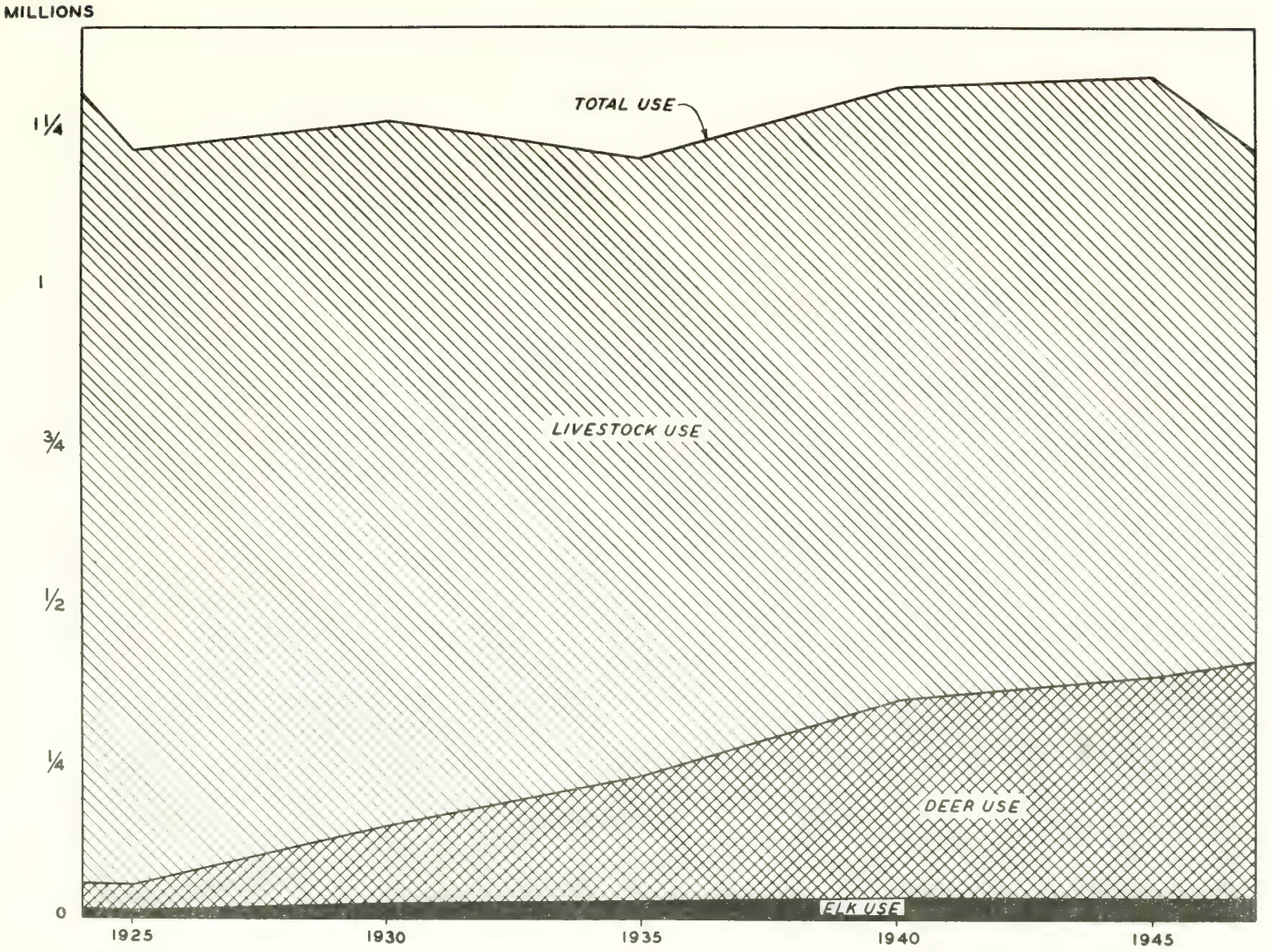

Figure 2. Grazing use on national forests in Utah in animal unit months, 1924-1947.

(AGRICULTURE - OGDEN)

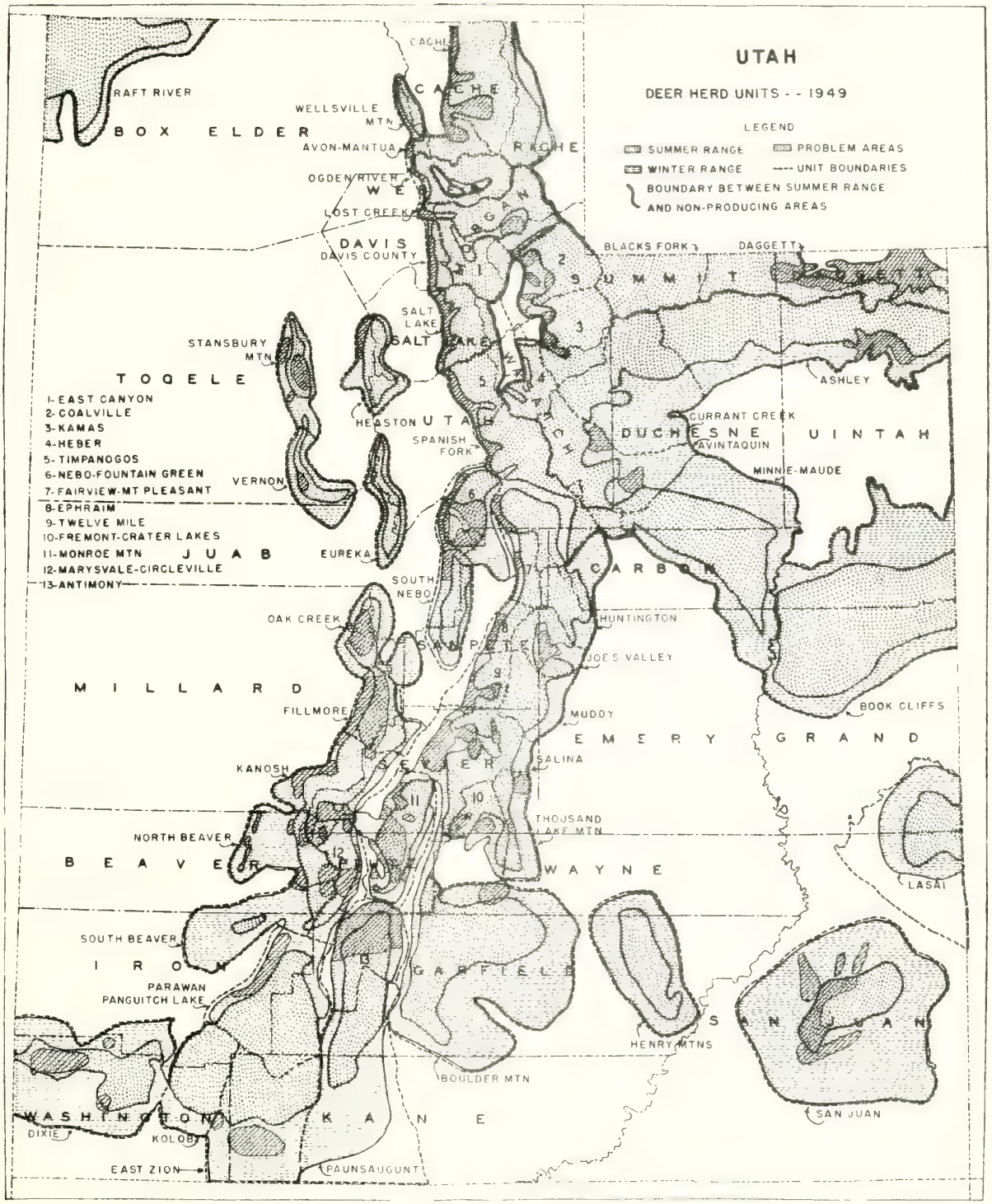

Figure 3. Deer management units, seasonal ranges and concentration areas in Utah. The concentration or problem areas are mostly deer winter ranges and livestock spring and fall ranges. Many of the concentration areas are on important watersheds.

(AGRICULTURE - LOGAN)

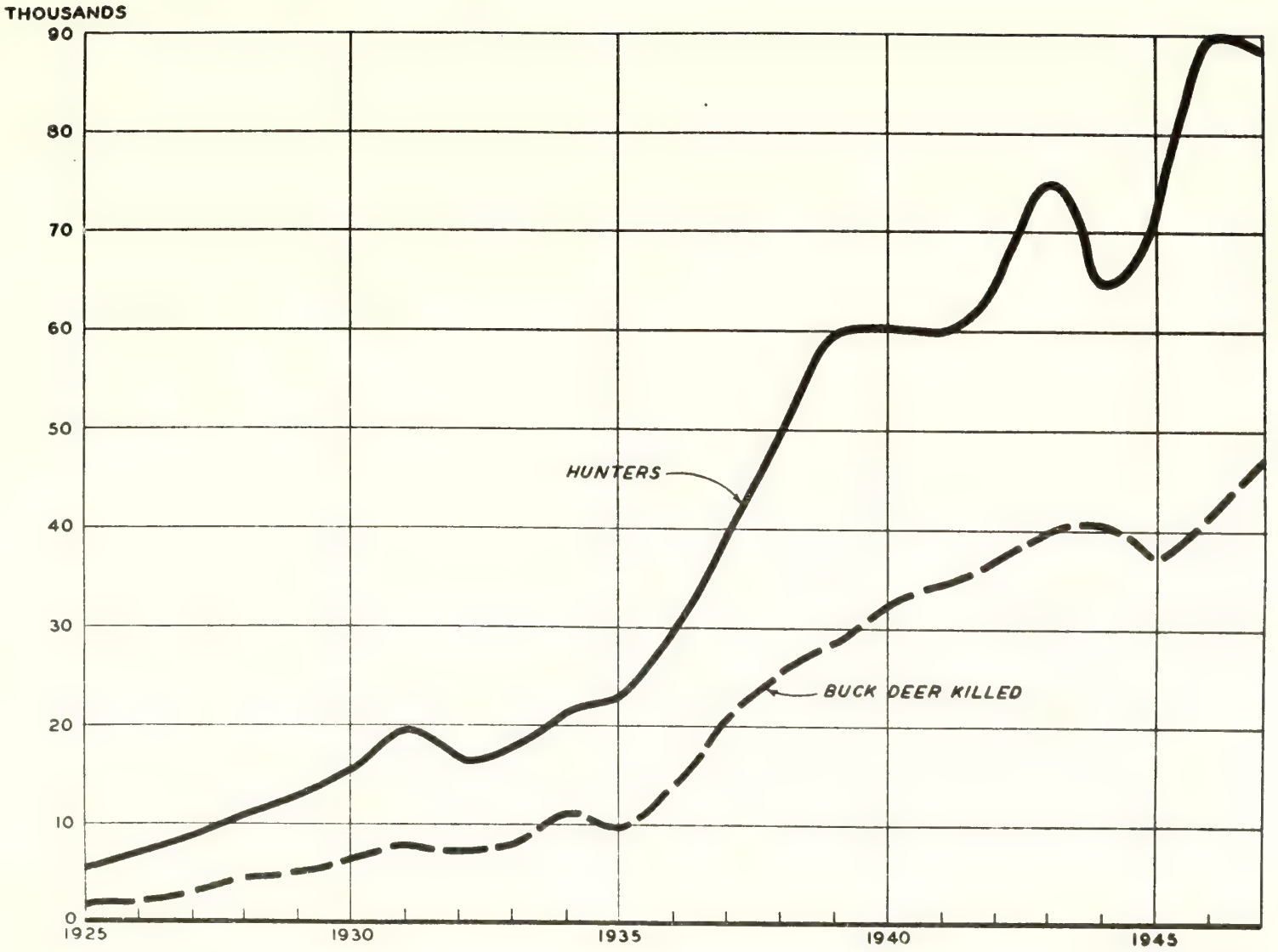

Figure 4. Trend in numbers of deer killed and numbers of deer hunters in Utah, 1925-1947.

(AGRICULTURE - OGDEN)

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U. S. Department of Agriculture
Forest Service, Ogden, Utah
Reed W. Bailey, Director

Research Paper No. 25 December 1950

ERADICATION OF WYETHIA 1/

Walter F. Mueggler and James P. Blaisdell, Range Conservationists

Wyethia (Wyethia amplexicaulis and W. helianthoides) is a relatively unpalatable perennial forb that has literally "taken over" thousands of acres of highly productive mountain meadows. Since this plant is such an aggressive competitor, it must be virtually eliminated before satisfactory stands of desirable forage species can be obtained.

Studies in the eradication of wyethia, and the consequent establishment of more desirable forage species, were conducted at two areas, Dry Creek and West Camas Creek, on the Spencer District of the Targhee National Forest in eastern Idaho.

The study on Dry Creek was started in 1947 primarily to compare cultural treatments for eradication of wyethia. The plots were reseeded immediately after cultivation. Preliminary chemical eradication treatments were made in 1948.

The results indicate that moldboard plowing, which destroyed about 75 percent of the wyethia, is an effective, though expensive, means of eliminating wyethia. After 3 years, successful stands of reseeded grasses on moldboard-plowed plots were producing over 13 times as much herbage as the grass component of the untreated checks. This method is limited to deep soils without numerous rock outcrops which would cause excessive breakage in equipment. Plowing must be followed with reseeding as all perennial vegetation is destroyed. Because of its limited applicability and high cost, moldboard plowing cannot be widely used. The other cultural methods investigated, disking with either a wheatland plow or offset disk, did not cause an appreciable reduction in wyethia.

Of the chemicals used on Dry Creek only 2,4-D appeared promising. This herbicide reduced wyethia production to 31 percent of that on the check plots; release from competition enabled the native grasses to increase to 326 percent of the check plots. Creosote and diesel oil, ammonium sulfamate, and kerosene were not effective in killing wyethia.

1/ A complete report of this study will appear in the May 1951 issue of the JOURNAL OF RANGE MANAGEMENT under the title, "Replacing Wyethia with Desirable Forage Species."

Studies with hormone weedkillers were made on West Camas Creek in the spring of 1949. Three herbicides, 2,4-D ethyl ester, 2,4,5-T butoxy ethanol ester, and a mixture of two parts 2,4-D and one part 2,4,5-T in butoxy ethanol ester form, were used on duplicated $\frac{1}{2}$-acre plots. Each herbicide was applied in water solution at two rates, 1 and 2 pounds acid equivalent per acre, during two growth stages of wyethia, "half bloom" and "blooming over." One replication of plots was seeded to grass in the fall of 1949.

Observations made 1 year after treatment show, on the basis of untreated check plots, that all the herbicides caused a considerable reduction in wyethia. This reduction varied from a 27 percent decrease by the least effective treatment, 2,4,5-T applied at 1 pound per acre at the "blooming over" stage; to a 95 percent decrease by the most effective treatments, 2,4,-D and the mixture applied at 2 pounds per acre at the "half bloom" stage. Grass production increased on nearly all treated plots, but these increases came from recovery of native grasses rather than from growth of artificially seeded species. The mixture and 2,4-D were comparable in degree of wyethia kill; however, because of its lower cost, 2,4-D was considered the more practical hormone weedkiller for widespread use. 2,4,5-T was not only the least effective hormone, but also the most expensive. In all cases, application of the herbicide at the early date, "half bloom" growth stage, was more effective than at the later date. A chemical concentration of 2 pounds acid equivalent per acre always proved considerably more detrimental to wyethia than 1 pound.

This study indicates that 2,4-D ethyl ester applied at 2 pounds acid equivalent per acre between "first and half bloom" is a comparatively economical and thorough means of eradicating wyethia. Native grasses were not greatly injured by this treatment and their recovery was very rapid. It is concluded, therefore, that reseeding is necessary only on areas that lack a fairly abundant and well-distributed understory of grasses.

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STATUS OF RESEARCH ON WATERSHED PROTECTION REQUIREMENTS FOR GRANITIC MOUNTAIN SOILS IN SOUTHWESTERN IDAHO

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STATUS OF RESEARCH ON WATERSHED PROTECTION REQUIREMENTS FOR GRANITIC MOUNTAIN SOILS IN SOUTHWESTERN IDAHO

By Paul E. Packer, Forester

INTRODUCTION

The mountain lands that constitute the upper drainage basins of the Boise, Payette, and Salmon Rivers in south-central Idaho have long presented a difficult watershed management problem. Much of the highly erosible, loose, granitic soil, characteristic of these drainages, has been exposed as a result of plant cover depletion, chiefly by fire, grazing, and logging. It is therefore highly vulnerable to displacement by raindrop impact and to erosion by overland flow, particularly during high intensity rains. This situation has led to abnormal flood discharges and accelerated sedimentation in water storage and transmission facilities upon which the region is dependent for maintenance of its primary economic endeavor--irrigation agriculture.

Watershed protection within the Boise River drainage basin has been under investigation intermittently since 1925. This report briefly reviews the findings of the earlier studies in this area, describes the research work of more recent years, and outlines the additional phases of research that are needed.

EARLY STUDIES

Extensive inspections in 1925-28 revealed the range portion of the Boise River watershed to be in seriously eroding condition. As a followup to these inspections, a more detailed range-erosion survey was made over a large portion of the Boise River watershed in 1929-30. In his report of this survey, Renner[1/] established some significant relationships.

1. Erosion was found to vary directly with the degree to which the plant cover has been depleted and the soil surface disturbed. Range lands comprised the areas of greatest depletion and were examples of the most severe erosion. The most serious erosion was found on south-facing aspects.

2. Erosion was found to vary directly with the steepness of slope, increasing up to about 35 percent gradient. On steeper slopes, other factors such as lighter grazing use interfered with evaluation of this relationship.

1/ Renner, F. G. Conditions influencing erosion on the Boise watershed. U. S. Dept. of Agr. Tech. Bull. 528, 32 pp., illus. 1936.

Subsequent surveys[2] by the Forest Service showed about 93 percent of the Boise River drainage to be in some degree of plant cover depletion attended by accelerated surface runoff and erosion. Approximately 5 percent of the drainage, mainly on the spring-fall grassland range is seriously depleted. About 61 percent in grassland range, brushlands, and cut-over and burned forest lands is moderately to severely deteriorated. Some 27 percent, mainly forest land, shows evidence of slight depletion. The remaining 7 percent, mostly in the protection forest, has not been damaged. A similar condition, in greater or lesser degree, exists on the Payette and Salmon River drainage basins.

In general, the lower mountain and foothill region is composed of an extensively depleted perennial wheatgrass (Agropyron inerme) range, This range has been largely invaded by the annual cheatgrass (Bromus tectorum) and is the major contributor of sediment to stream channels and irrigation structures.

Love and Benedict[3] measured sediment loads at 13 gaging stations within the Boise River watershed. All of the gaged drainages had a granitic soil mantle. The plant cover on the test areas varied from timbered forest land to grassland range. The condition of the plant cover included virgin, cut-over, and burned forest land and fairly good, moderately deteriorated, and severely depleted range land. These records indicate that sediment loads are, in general, less from forested areas than from grassland range. They also indicate that sediment loads are greater from logged and burned forest land, and greatest from depleted range land.

Craddock and Pearse,[4] employing an infiltrometer plot technique, evaluated the relative effects of precipitation intensity, slope, gradient, soil disturbance, and four different kinds of plant cover on surface runoff and erosion in the Boise River watershed. They concluded that high-intensity rainfall was potentially highly destructive on steep slopes where the soil surface had been disturbed and especially so on annual cover following perennial plant cover depletion. They also concluded that even moderate intensity rainfall could be dangerous except under extremely good plant cover conditions. The specific conditions of plant cover necessary for protection were, however, not determined.

2/ U. S. Department of Agriculture. Survey report on program of runoff and waterflow retardation and erosion prevention for flood control purposes. Boise River drainage basin, Idaho. 37 pp. 1943.

3/ Love, S. K., and Benedict, P. C. Discharge and sediment loads in the Boise River drainage basin, Idaho, 1939-1940. U. S. Dept. of the Interior, Geological Survey Report. 1940.

4/ Craddock, G. W., and Pearse, C. K. Surface runoff and erosion on granitic mountain soils of Idaho as influenced by range cover, soil disturbance, slope, and precipitation intensity. U. S. Dept. of Agr. Cir. 483, 24 pp., illus. 1938.

The investigations up to this point clearly indicated south-facing aspects of depleted spring-fall range to be the most serious sediment-source areas. The studies were not sufficiently refined, however, to determine the particular characteristics of these range lands that are responsible for accelerated runoff and erosion, nor did they develop specific requirements in terms of observable site characteristics for minimizing overland flow and stabilizing soil.

1947 SITE CHARACTERISTIC STUDY

In 1947 a new study was made to determine which of several readily observable site characteristics of the wheatgrass and cheatgrass range types were related to summer storm runoff and erosion. The site characteristics investigated were:

1. Total ground cover (basal area of plants plus surface litter). Total ground cover values were generally 75 to 100 percent greater than range survey plant density values.

2. Maximum site of bare soil openings. (Greatest diameter of openings measured from edges of litter patches on the ground.)

3. Aerial plant cover density, the area of the plant canopy projected on the ground.

4. Erosion pavement.

5. Root abundance.

6. Noncapillary soil pore space.

7. Capillary soil pore space.

8. Soil depth.

9. Slope gradient.

The study was made in the 200-acre Woodtick Creek exclosure which had been closed to grazing for 17 years. Because of this protection from grazing, considerably more litter had accumulated around the base of the plants and beyond the projected area of the plant canopy than on adjacent grazed range. Within the study area 14 wheatgrass and 16 cheatgrass sites were subjected to 1.8 inches of artificial rainfall in 30 minutes by means of a modified, 6- x 6-foot, type F infiltrometer.

This study[5/] yielded the following significant findings:

5/ Packer, P. E. An approach to watershed protection requirements, Journal of Forestry, 49:639-644. 1951.

1. Total ground cover and size of bare soil openings were found to be the two site characteristics which dominantly control the amount of storm runoff and erosion from both cover types. Total ground cover exercised the greatest control over runoff whereas the size of bare soil openings was the most effective single characteristic influencing erosion.

2. Runoff and erosion on both range sites decreased with an increase in total ground cover up to a level of about 70 percent. This amount of ground cover occurred on sites having a plant cover density of from 35 to 45 percent. Additional amounts of ground cover were not materially effective in further decreasing runoff or erosion.

3. The characteristics of soil depth, erosion pavement, and root abundance were each closely related to runoff and erosion, but their influence in controlling these losses was much less than the influence of ground cover and bare soil openings.

4. The other characteristics, aerial plant density, capillary soil pore space, noncapillary soil pore space, and slope gradient, appeared to have no significant relation either to runoff or erosion.

The absence of any significant influence on runoff or erosion by aerial plant cover is probably attributable to the controlling influence of the litter cover. Litter on the ground appeared to provide about as effective protection on the test plots where aerial plant cover had been removed by clipping as did litter and aerial plant cover together on the unclipped plots. Plant cover which occurs over bare soil, such as is commonly found on ranges where persistent heavy utilization decreases or precludes accumulation of litter, may exert more protective influence than was found in these tests on undisturbed range.

Soil pore space showed no definite relation to either runoff or erosion probably because most of the pore space in the sandy granitic soil was greater than the pore space values that have a restrictive effect on percolation. It is possible that soil pore space may be so reduced by the compacting effect of trampling as to exert a restrictive effect on percolation and thus become a more significant site characteristic than this study revealed it to be. It is believed, however, that this possibility is somewhat problematical on the steep slopes where trampling tends to displace the loose granitic soil downhill rather than to compact it.

The lack of any significant effects on runoff or erosion by variations in slope gradient appears to be due to the limited length of the test plots. Little rilling or gullying was observed on the plots during the tests and concentrations of runoff into small channels did not develop. On longer slopes, where greater opportunity exists for such concentrations, tests will very probably reveal that slope gradient is of more importance than indicated in this study.

This study, though based on a limited number of tests on undisturbed range, indicated total ground cover and size of bare soil openings to be potentially useful criteria of watershed conditions. Additional tests, however, seemed desirable to more definitely establish the specific amounts of ground cover and sizes of bare soil openings that are required to minimize overland flow and soil erosion.

STUDY OF GROUND COVER AND BARE SOIL OPENING EFFECTS

In 1948, additional infiltrometer tests were made on eight wheatgrass and eight cheatgrass sites within the Woodtick Creek study area. These, together with the 1947 tests, provided data from 22 wheatgrass sites and 24 cheatgrass sites. Ground cover on the wheatgrass test sites ranged from about 96 percent to about 10 percent and on the cheatgrass sites from about 94 percent to about 14 percent. Bare soil openings varied from less than 1 inch to as much as 38 inches on wheatgrass sites and from less than 1 inch to 49 inches on the cheatgrass sites. Storm runoff ranged from zero to nearly 28 percent on the wheatgrass sites and from zero to nearly 42 percent on the cheatgrass sites. Eroded soil varied from zero to 3,358 pounds per acre (dry weight) on wheatgrass sites and from 1 to 3,620 pounds per acre on the cheatgrass sites (table 1).

The data were subjected to multiple curvilinear regression analyses. One set of analyses examined the relationship between ground cover and overland flow and the manner in which this relationship is affected by the size of bare soil openings. The other set of analyses provided information on the relationship of bare soil opening size to erosion and how this relationship is influenced by total ground cover.

Effects on Storm Runoff

The curves in figure 1-A illustrate the average net effect of ground cover on overland flow. These curves show that, with a ground cover of 10 percent, expected amounts of overland flow are about 27 percent from the wheatgrass cover and 45 percent from the cheatgrass cover. With a ground cover of 70 percent, overland flow from the wheatgrass and cheatgrass sites is about 11.5 percent and 6.3 percent, respectively. At 90 percent ground cover, overland flow from these two respective kinds of plant cover is about 11.3 percent and 6.2 percent. An increase in ground cover from 10 percent to 70 percent, therefore, results in an appreciable decrease in overland flow from both kinds of cover. On the other hand, a further increase in ground cover beyond 70 percent is not materially effective in further reducing overland flow. Because the average amount of overland flow is not appreciably reduced by ground cover in excess of 70 percent, a minimum of about 70 percent ground cover appears to be required for control of storm runoff.

The relationship of overland flow to ground cover may be influenced, however, by the size of bare soil openings between patches of litter and plants. The curves in figure 1-B show that the overland flow associated with the wheatgrass ground cover may be increased by as much as 4.0 percent with bare soil openings of 40 inches and reduced by as

Table 1.--Runoff and erosion from ungrazed wheatgrass and cheatgrass sites at different conditions of total ground cover and bare soil openings, Woodtick Creek exclosure, 1947-48

Wheatgrass				Cheatgrass			
Total ground cover	Bare soil opening	Over-land flow	Soil ero-sion	Total ground cover	Bare soil opening	Over-land flow	Soil ero-sion
Percent	Inches	Percent	Lbs./A.	Percent	Inches	Percent	Lbs./A.
95.8	0	0	0	94.0	0	0	1
94.4	2	2.36	104	94.0	0	7.10	55
93.0	0	.50	0	91.7	5	5.40	669
90.0	1	3.00	98	86.2	5	3.91	625
80.5	3	9.25	460	86.2	4	4.49	462
80.0	1	3.60	9	80.5	15	8.13	1,429
76.0	4	7.40	439	72.0	0	1.50	21
61.0	6	7.50	701	70.0	1	2.00	10
50.0	15	13.90	1,238	64.0	2	4.60	97
47.2	15	10.76	1,325	52.0	7	10.00	858
33.0	7	9.60	1,090	33.0	33	19.40	2,499
31.2	16	18.11	1,586	32.0	7	14.10	1,066
30.6	10	14.51	1,476	27.8	31	15.37	2,410
30.5	12	18.97	1,520	27.1	10	19.26	1,349
29.1	2	9.71	540	26.4	4	15.70	955
28.0	5	14.90	905	26.4	6	19.00	1,171
27.8	38	23.78	2,564	26.4	23	19.67	1,926
22.2	6	27.76	1,332	25.0	9	20.95	1,369
18.1	25	24.45	2,103	25.0	12	30.33	1,720
16.7	4	12.91	970	23.6	7	18.88	1,388
16.6	14	22.45	1,983	20.8	19	26.39	1,939
10.4	38	22.12	3,358	20.1	24	32.21	2,148
				19.4	29	31.04	2,555
				13.9	49	41.73	3,620

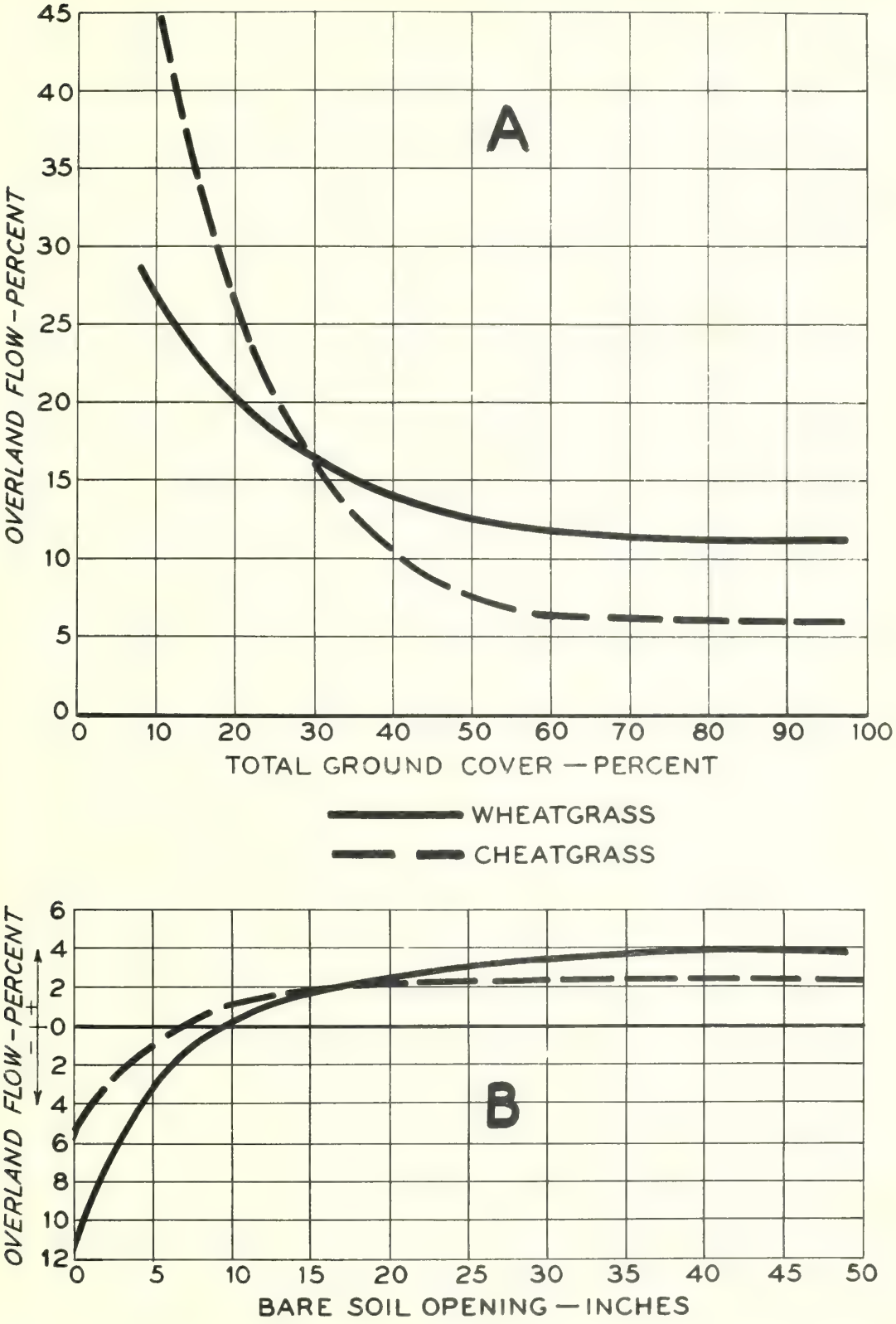


Figure 1.--Average net overland flow (A) as related to ground cover and (B) as affected by bare soil opening.

(AGRICULTURE - OGDEN)

much as 11.3 percent with an opening of zero. Similarly, the influence on overland flow associated with cheatgrass ground cover ranges from increases of as much as 2.3 percent at bare openings of 50 inches to reductions of as much as 5.2 percent at openings of zero. This means that larger bare soil openings decrease the effectiveness of ground cover in controlling overland flow whereas smaller openings increase its effectiveness. It appears, therefore, that the effectiveness with which ground cover controls overland flow is contingent upon the extent to which the size of bare soil openings approaches zero.

Effects on Erosion

The average net effect of bare soil openings on soil erosion is shown by the curves in figure 2-A. These curves reveal that at a bare soil opening of 40 inches, soil erosion is about 2,600 pounds per acre from both the wheatgrass and cheatgrass sites. With a reduction in the size of the bare soil opening, the amount of soil erosion is also reduced until with an opening of zero, the amount of soil erosion is about 200 pounds per acre from both kinds of range. The curves show that the greatest rate of decrease in erosion occurs within the bare opening range from 10 inches to zero. They also reveal that there is no range of bare opening values over which the amount of erosion is not materially changed. The extent to which bare soil openings approach zero, therefore, appears to determine just how effectively soil erosion can be controlled.

The amount of soil erosion associated with bare soil opening may be influenced, however, by the amount of ground cover. The curves in figure 2-B show that the amount of soil erosion associated with any size of bare opening is increased by about 880 pounds per acre in the wheatgrass cover and by about 740 pounds per acre in the cheatgrass cover when the ground cover is 10 percent. With a ground cover of 70 percent the amount of erosion is reduced by as much as 260 pounds per acre on wheatgrass sites and 190 pounds per acre on cheatgrass sites. At 90 percent ground cover, reductions in erosion are only slightly greater than at 70 percent, being about 270 pounds per acre in wheatgrass and about 200 pounds per acre in cheatgrass. Thus, the amount of erosion associated with bare soil opening is not further reduced materially in either kind of cover by ground cover in excess of 70 percent. One of the requisites for control of erosion, therefore, appears to be a minimum ground cover of about 70 percent.

PROTECTION REQUIREMENTS FOR UNDISTURBED RANGE

The relationships shown by the regression curves in figures 1 and 2 are in terms of average net values of each of the controlling characteristics of ground cover density and bare soil opening. These average net relationships do not provide sufficient information to be of use for management purposes, however, for they reveal nothing concerning the manner in which the values of these two characteristics actually occur in combination on the wheatgrass and cheatgrass lands.

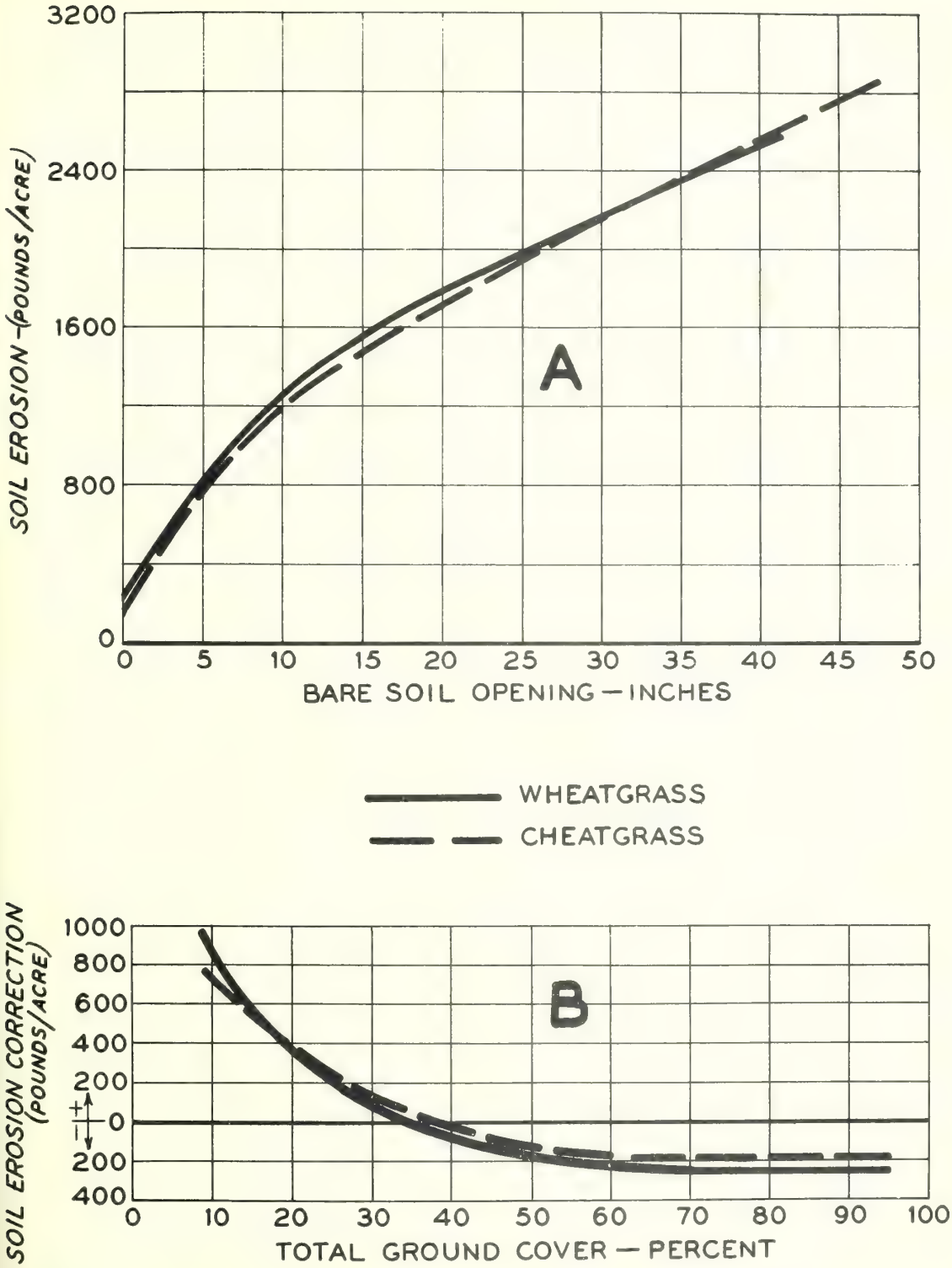


Figure 2.—Average net soil erosion (A) as related to bare soil opening and (B) as affected by ground cover.

Occurrence of Ground Cover and Bare Soil Opening

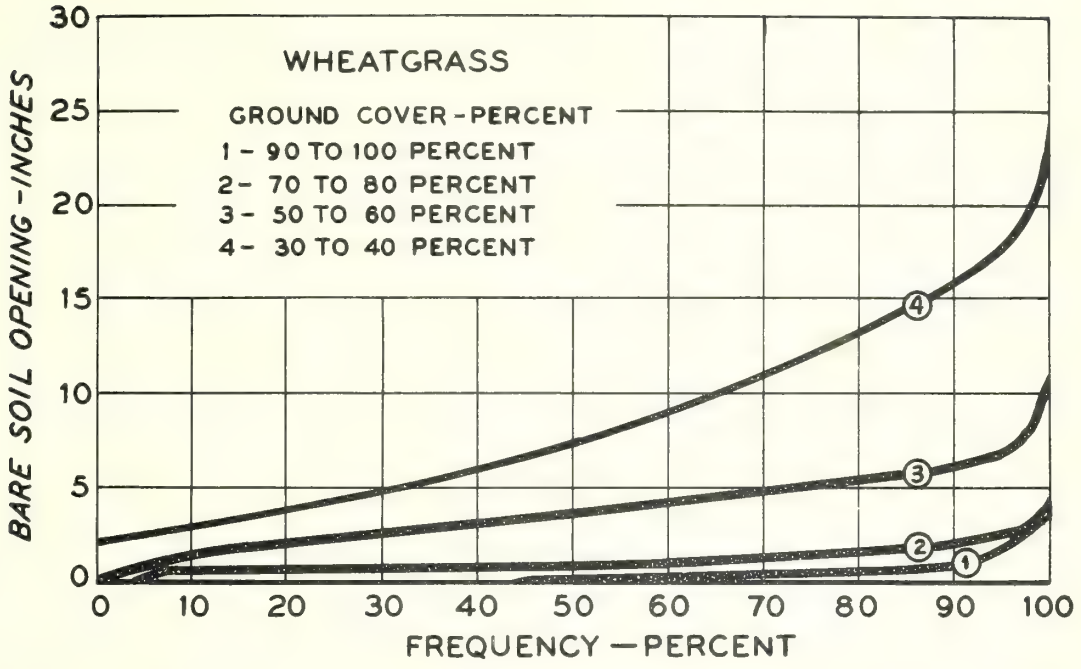
Measurements of ground cover and bare soil opening were obtained in 1948 on 200 wheatgrass and 200 cheatgrass sites within the original study area. Within each kind of plant cover the plots were located by stratifying them into ground cover classes of 30 to 40 percent, 50 to 60 percent, 70 to 80 percent, and 90 to 100 percent and then systematically locating 50 plots in each class. In each kind of cover the relationship between ground cover and bare soil opening was determined by developing frequency-distribution curves showing the percentage distribution by sizes of bare soil openings throughout the selected ground cover classes (fig. 3).

These curves reveal that, in both kinds of cover, the maximum size and the range of variation in size of bare soil openings became smaller as the amount of ground cover increased. The cheatgrass cover exhibited a more pronounced tendency toward a narrower range of small-sized openings than did wheatgrass of comparable ground cover. This was apparently due to the tendency of cheatgrass to grow in stands having a more uniform distribution of individual plants--and hence patches of litter--than did wheatgrass, thereby resulting in bare soil openings which, though perhaps greater in number, were smaller in size with given amounts of ground cover. The small standard errors in table 2 reflect the close dispersion of individual observations of bare opening size about the frequency distribution curves, indicating that these curves may be employed with reliability to show the bare opening size--ground cover relationships.

Table 2.--Standard error in size of bare soil openings associated with different ground cover densities

Ground cover density	Standard error	
	Wheatgrass	Cheatgrass
Percent	Inches	Inches
90 to 100	0.1	0.1
70 to 80	.1	.1
50 to 60	.3	.2
30 to 40	.7	.4

The ground cover-bare soil opening relationships shown by the curves in figure 3 furnish a basis, in conjunction with figures 1 and 2, for estimating the amounts of overland flow and erosion that may be expected to occur under ground cover and bare opening conditions that actually exist together on ungrazed range. In figure 3, for example, curve number 1 for wheatgrass shows that a bare soil opening of 4 inches was not exceeded where the prevailing ground cover was at least 90



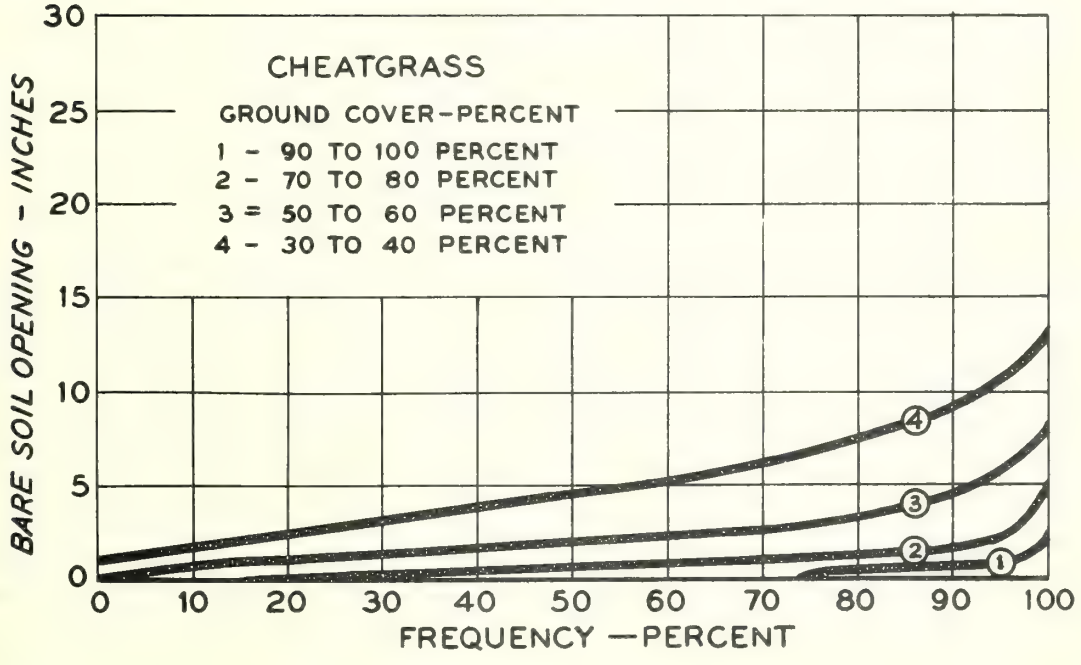


Figure 3.--Frequency distribution of bare soil opening sizes with varying ground cover on wheatgrass and cheatgrass sites.

percent. These respective values, when applied to the curves for wheatgrass in figures 1-A and 1-B, reveal that the amount of overland flow from a ground curve of 90 percent was about 11.3 percent but that this amount was subject to a reduction of 4.1 percent under the influence of a 4-inch bare soil opening. Thus, the estimated maximum overland flow from this combination of ground cover and bare opening was about 7.2 percent. Extending this procedure by utilizing the ground cover-bare opening relationships from the other curves in figure 3, maximum amounts of overland flow and erosion to be expected from wheatgrass and cheatgrass cover in 100 percent of cases were estimated (table 3).

Table 3.--Maximum bare soil opening and maximum amounts of overland flow and erosion occurring in 100 percent of cases from wheatgrass and cheatgrass sites at different amounts of ground cover

Minimum ground cover	Wheatgrass			Cheatgrass		
	Bare soil opening	Overland flow	Soil erosion	Bare soil opening	Overland flow	Soil erosion
Percent	Inches	Percent	Lbs./A	Inches	Percent	Lbs./A
90	4	7.2	455	2	3.2	261
70	4	7.3	460	5	5.4	625
50	11	13.1	1,147	8	8.2	965
30	25	19.5	2,072	13	17.8	1,375

Control Requirements on Wheatgrass Range

The values in table 3 reveal that the same 4-inch maximum bare opening was encountered in wheatgrass sites of 90 percent and 70 percent ground cover. The maximum amounts of overland flow and of erosion from each of these two combinations of ground cover and bare opening are also revealed to have been very nearly the same. On the other hand, with ground cover of less than 70 percent the size of the largest bare openings was materially greater, being 11 inches when ground cover was as low as 50 percent. Under these conditions the amount of overland flow was nearly double that from a ground cover of 70 percent and the amount of soil erosion was more than doubled. Similarly, still greater amounts occurred from ground cover as low as 30 percent, in which the maximum bare openings had increased in size to 25 inches. When all cases were considered, therefore, the most effective overland flow and erosion control to be expected from the ground cover and bare opening conditions actually encountered on the wheatgrass lands appeared to be provided about equally well by any ground cover amount in excess of 70 percent together with bare soil openings of 4 inches or less. It may

be concluded, therefore, that a ground cover of at least 70 percent and a bare opening of no more than 4 inches constitute essential maximum requirements for effective protection of undisturbed wheatgrass watershed lands against the destructive effects of high intensity summer rainstorms.

Control Requirements on Cheatgrass Range

Referring again to table 3 the requirements for effective control of overland flow and erosion in cheatgrass range appeared to result from ground cover of 90 percent or more in combination with bare soil openings of no more than 2 inches. With lesser amounts of ground cover the size of bare openings was appreciably greater, being 5 inches at a ground cover of 70 percent. These conditions permitted an amount of overland flow nearly double that from a ground cover of 90 percent and an amount of soil erosion that was more than doubled. Still larger amounts occurred from lesser amounts of ground cover in which the size of maximum bare openings was substantially greater. There was no range comparable to that on wheatgrass lands over which combinations of cheatgrass ground cover and bare soil opening may be varied without altering their effectiveness for controlling overland flow and erosion. The requirements for effective protection of undisturbed cheatgrass watersheds, therefore, appear to be a ground cover of at least 90 percent and a bare soil opening of not more than 2 inches.

Curve number 2 for cheatgrass in figure 3 shows, however, that a maximum bare soil opening of 2 inches was encountered in 94 percent of cases where ground cover was as low as 70 percent. The maximum amounts of overland flow and erosion under these conditions were estimated from figures 1 and 2 to be 3.3 percent and 263 pounds per acre, respectively. These amounts were very nearly equal to the values of 3.2 percent overland flow and 261 pounds per acre of eroded material which occurred from a combination of 90 percent density and 2-inch bare opening (table 3). Accordingly, in 94 percent of cases encountered, about equally effective control appeared to be provided by any combination of ground cover as low as 70 percent with bare soil opening of 2 inches. In the remaining 6 percent of cases, a ground cover of no less than 90 percent was necessary for an equal degree of control. It may be concluded, therefore, that in by far the majority of cases a ground cover of at least 70 percent and a bare soil opening of no more than 2 inches comprise the necessary minimum requirements for effective protection of undisturbed cheatgrass watersheds on granitic soils.

EFFECT OF HEAVY TRAMPLING DISTURBANCE

An exploratory investigation was begun in 1948 to determine whether the control requirements previously developed for undisturbed range were equally effective in providing satisfactory protection in the presence of current heavy trampling disturbance. Of necessity, this initial investigation was limited to a small number of tests consisting of one infiltrometer plot on each of eight wheatgrass and seven

cheatgrass sites. Within the sampling limitations imposed by this small number of tests, an attempt was made to locate the plots so as to include a variety of ground cover and bare soil opening values from well above to appreciably below the minimum protection requirements developed for undisturbed conditions.

On the basis of surface disturbance observed on heavily grazed portions of the range, it was estimated that heavy trampling may reasonably be expected to disturb about 60 percent of the area in some degree. Accordingly, prior to the tests, all plots were subjected to a single disturbance treatment in which 60 percent of the ground surface was uniformly trampled by impact of an iron "hoof."

Ground cover and bare soil opening measurements were made on the plots before and after the trampling treatment. After trampling, the plots were subjected to 1.8 inches of rainfall in 30 minutes with the infiltrometer as in previous tests.

Trampling disturbance decreased the total ground cover and increased the size of bare soil openings on both range types in all but one case. On one of the cheatgrass plots, trampling increased the ground cover from 55 to 58 percent. This slight increase may have been due to estimation error or to the redistribution of plant and litter material. In this instance, however, the size of the largest bare soil opening was increased from 3 to 10 inches (table 4). Precisely how these changes were effected is not fully known. It was observed on the plots and on grazed range, however, that the impact of hoofs tended to push both soil and litter down hill. This tended to pile up the litter, thus increasing the size of already existing bare soil openings or creating new openings.

The measured amounts of runoff and erosion obtained from the trampled plots are also shown in table 4 together with estimated amounts derived from the curves shown in figures 1 and 2, the latter being based upon previous measurements on undisturbed plots. These data provided a basis for comparing runoff and erosion from disturbed and undisturbed sites having the same ground cover and bare soil openings; also for comparing estimated amounts of runoff and erosion from undisturbed sites with measured amounts from disturbed sites having ground cover and bare soil openings prior to trampling similar to the undisturbed sites.

Runoff and erosion from the trampled plots did not differ significantly from the estimated amounts from undisturbed plots having ground cover conditions comparable to those on the trampled plots after disturbance. This indicates that regardless of trampling disturbance the runoff and erosion behavior of the granitic soil on these range types is primarily controlled by the amount of ground cover and the size of bare soil openings.

The observed amounts of runoff and erosion from the trampled plots were significantly greater than the estimated amounts from undisturbed sites having ground cover conditions comparable to those

Table 4.--Total ground cover, size of bare soil opening, storm runoff, and soil erosion from wheatgrass and cheatgrass range before and after 60 percent trampling disturbance

Total ground cover		Bare soil opening		Storm runoff			Soil erosion		
				Disturbed		Natural	Disturbed		Natural
Natural	Disturbed	Natural	Disturbed	Observed	Estimated1/	Estimated2/	Observed	Estimated1/	Estimated2/
Percent	Percent	Inches	Inches	Percent	Percent	Percent	Lbs./A.	Lbs./A.	Lbs./A.
					Wheatgrass				
92	77	2	4	7.9	7.1	4.1	496	460	220
90	83	1	3	6.9	5.7	.0	344	340	100
83	78	3	8	7.7	10.7	5.7	791	840	340
72	58	4	8	13.1	11.4	7.2	917	870	460
64	58	3	5	7.8	8.9	6.1	602	590	350
55	50	18	28	13.7	16.0	14.5	1,963	1,960	1,540
44	36	32	46	22.2	18.8	16.6	2,859	2,800	2,090
32	29	13	18	17.0	19.2	17.1	2,056	1,820	1,565
Average	-	-	-	12.0	12.2	8.9	1,254	1,198	833
					Cheatgrass				
94	88	1	3	2.1	4.1	2.0	452	360	110
72	61	1	2	5.6	3.5	2.2	361	250	115
60	42	13	26	16.9	12.2	8.3	1,356	1,930	1,250
55	58	3	10	11.1	7.9	4.8	454	960	380
49	28	22	40	29.1	20.2	10.7	2,900	2,730	1,650
42	27	15	39	28.6	21.1	11.7	2,827	2,720	1,440
28	16	20	44	33.6	35.1	20.1	3,438	3,180	1,910
Average	-	-	-	18.1	15.0	8.5	1,684	1,733	979

1/ Estimated amounts from undisturbed sites having ground cover conditions comparable to those on trampled sites after disturbance.

2/ Estimated amounts from undisturbed sites having ground cover conditions comparable to those on trampled sites before disturbance.

on the trampled plots before disturbance. On the average, 60 percent trampling disturbance stepped up runoff about 50 percent on wheatgrass sites and 110 percent on cheatgrass sites. This level of trampling also increased erosion 50 percent on wheatgrass sites and 72 percent on cheatgrass sites. These increases appear to result from decreases in ground cover and increases in the size of bare soil openings caused by trampling.

For each range type, regressions were developed between the measured amounts of runoff and erosion from the trampled plots and the estimated amounts from undisturbed sites having ground cover conditions comparable to those on the trampled plots prior to their disturbance. These regressions provided a basis for determining the ground cover conditions that are necessary, under the impact of 60 percent disturbance, to insure the same degree of runoff and erosion control as is provided by the minimum requirements for effective control on undisturbed range.

Control Requirements on Heavily Trampled Wheatgrass Range

It should be recalled that the minimum protection requirements for undisturbed wheatgrass range included a ground cover of at least 70 percent and a bare soil opening of no more than 4 inches. The amounts of overland flow and of erosion to be expected under these conditions have been shown in table 3 to be 7.3 percent and 460 pounds per acre, respectively. The regression lines in figure 4 show that if the observed overland flow and erosion from heavily trampled sites was not to exceed the above minimum amounts, then the estimated amounts to be expected from these sites had they not been trampled would on the average not have exceeded approximately 4.0 percent overland flow or 160 pounds per acre of soil erosion.

The combination of lowest ground cover and greatest bare soil opening that could be expected to hold runoff to less than 4.0 percent and erosion to less than 160 pounds per acre on undisturbed sites was determined from the curves in figures 1, 2, and 3. The curve for wheatgrass in figure 1-A shows that for any ground cover in excess of 70 percent, the overland flow was approximately 11.3 percent; for lesser amounts of ground cover it was somewhat greater. Figure 1-B shows that to reduce this amount to 4.0 percent, or in other words by 7.3 percent, requires a bare soil opening of about 2 inches. Similarly, figures 2-A and 2-B show that for any ground cover in excess of 70 percent, a bare opening of no more than 2 inches is necessary to insure that soil erosion would not exceed 160 pounds per acre. In figure 3, curve number 2 for whatgrass shows that a ground cover as low as 70 percent and a bare opening of no more than 2 inches could actually be expected together in only 88 percent of cases. On the other hand, curve number 1 shows that these same openings of 2 inches or less could be expected to occur with ground cover of no less than 90 percent in about 96 percent of cases. It appears, therefore, that in the vast majority of cases, protection of heavily trampled wheatgrass range, equivalent to that furnished by the control requirements for undisturbed range, requires ground cover of at least 90 percent together with bare

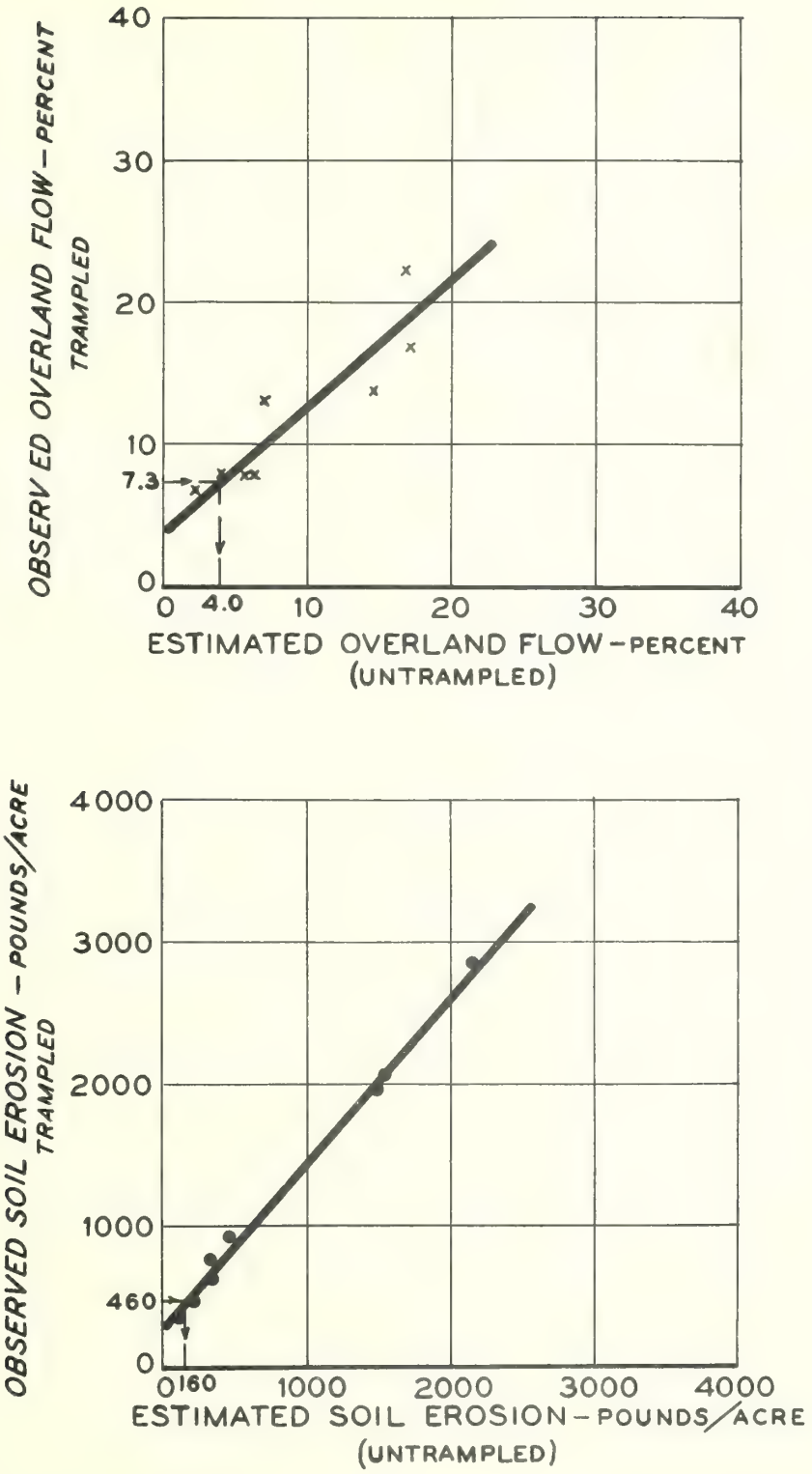


Figure 4.--Relation of estimated amounts of overland flow and soil erosion from untrampled wheatgrass sites to observed amounts occurring from comparable sites after heavy trampling.

soil openings of no more than 2 inches. These requirements are somewhat more stringent than those found to be necessary on undisturbed wheatgrass range.

Control Requirements on Heavily Trampled Cheatgrass Range

The minimum protection requirements for undisturbed cheatgrass range have been shown to include a ground cover of at least 70 percent and a bare soil opening of no more than 2 inches. The amounts of overland flow and of erosion to be expected under these conditions have also been shown to be 3.3 percent and 263 pounds per acre, respectively. Figure 5 shows that in order for these amounts not to be exceeded on heavily trampled sites, the estimated amounts from these same sites prior to trampling would probably not have exceeded about 2.0 percent overland flow or 140 pounds per acre of soil erosion.

By utilizing the curves for cheatgrass in figures 1 and 2 in the same manner as was done for wheatgrass it was found that a ground cover in excess of 70 percent together with a bare soil opening of no more than 1 inch was necessary to insure that runoff would not exceed 2.0 percent and soil erosion would not be more than 140 pounds per acre. Curve number 2 for cheatgrass in figure 3 shows that a ground cover as low as 70 percent and a bare opening of 1 inch or less could actually be expected together in only about 70 percent of cases. Obviously then, in nearly a third of cases, these conditions would not provide the desired control. Curve number 1 in figure 3 shows, however, that a combination of 90 percent ground cover and 1 inch of bare opening could be expected to occur in about 96 percent of cases. When the preponderance of cases is considered, therefore, a ground cover of at least 90 percent and a bare soil opening of no more than 1 inch appear to be necessary requirements on heavily trampled cheatgrass range to insure protection equivalent to that provided by the minimum control requirements on undisturbed range.

Achievement of 90 percent cover and bare openings of 1 or even 2 inches is probably impossible on all but a small portion of the wheatgrass-cheatgrass range due to inherently poor conditions for plant growth. Consequently, it appears highly improbable that effective watershed protection can be obtained on any practical scale under disturbance as intensive as 60 percent. Livestock grazing use of this spring-fall range will, therefore, have to be based on some lesser degree of disturbance, if any.

REMAINING RESEARCH PROBLEMS

Watershed research in southwest Idaho thus far has focused attention on developing protection requirements for south-facing aspects of the wheatgrass and cheatgrass range having steep slopes and a coarse granitic soil. An infiltrometer approach has been employed rather than the more costly and time-consuming method of using entire watersheds. It is recognized that infiltrometer data do not give direct answers to

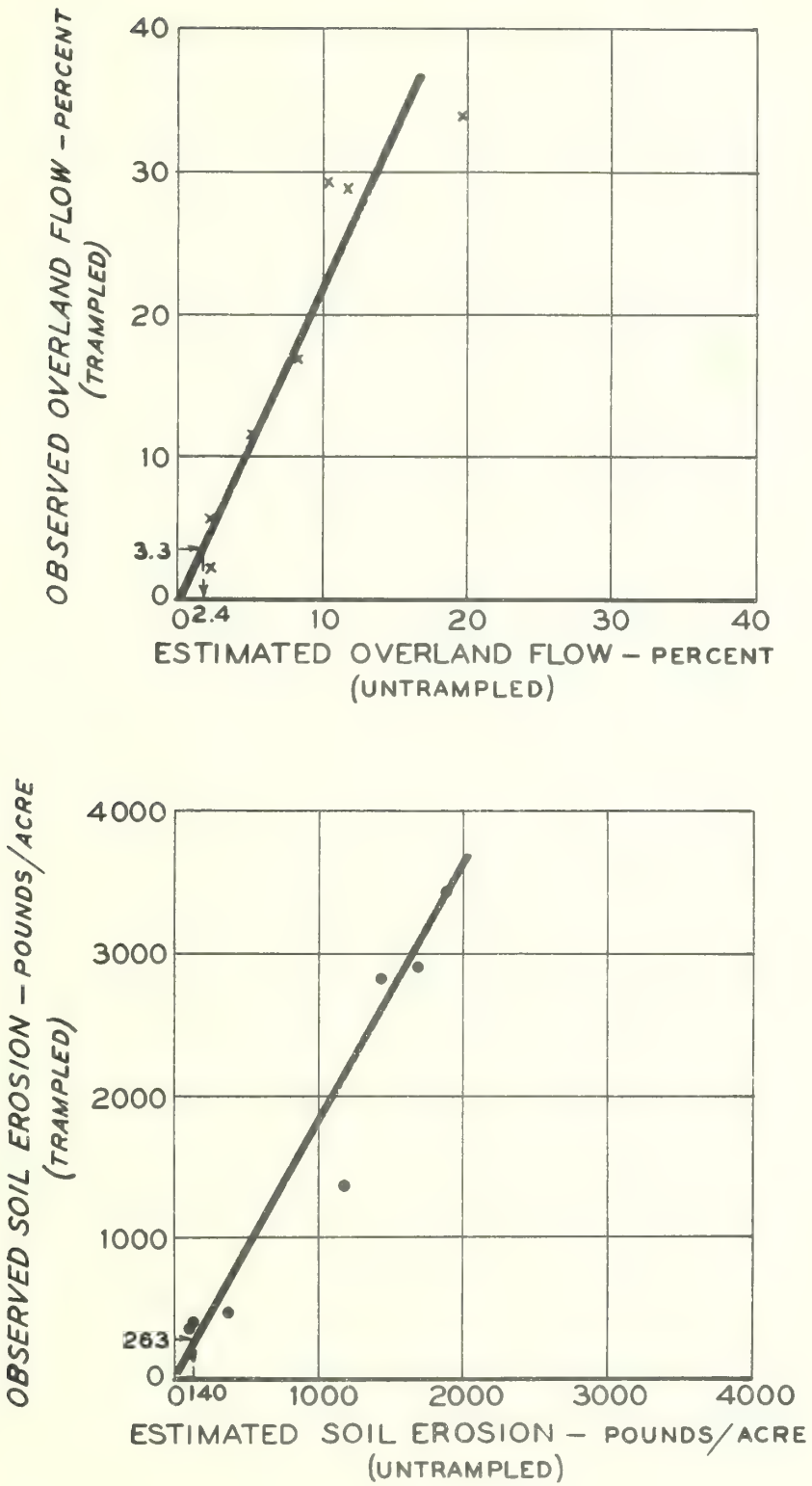


Figure 5.--Relation of estimated amounts of overland flow and soil erosion from untrampled cheatgrass sites to observed amounts occurring from comparable sites after heavy trampling.

the amounts of runoff or sediment to be expected from an entire drainage basin. Small plot tests, however, do provide information on the runoff and erosion behavior of local sites. When protection requirements for the most vulnerable sites are understood and met, it seems reasonable to expect that the less critical sites will also be taken care of.

Studies thus far have shown rather conclusively that total ground cover and size of bare soil openings are reliable criteria for judging watershed conditions on the wheatgrass and cheatgrass portions of the spring-fall range. They have also established that a ground cover of 70 percent--generally attained by a plant density of 35 to 45 percent--and a bare soil opening of no more than 4 inches on wheatgrass areas and of no more than 2 inches on cheatgrass areas is required for minimizing runoff and erosion during moderately high rainfall rates on undisturbed range. They have also indicated that heavy trampling disturbance so increases runoff and erosion as to make such disturbance incompatible with practicable watershed protection.

Several questions remain to be answered regarding the watershed protection problem on the granitic soils of southwestern Idaho. On the wheatgrass and cheatgrass range, the question remains as to whether some lighter degree of trampling disturbance may be consistent with the maintenance of ground cover conditions that are both practicable of attainment and effective for watershed protection purposes. It is proposed to answer this question in two steps: (1) by an infiltrometer study of the effects of several degrees of mechanical trampling disturbance on runoff and erosion, and (2) by an observational study of the effects of different degrees of cattle and sheep grazing disturbance on ground cover and bare soil openings. There is need for extending similar infiltrometer and grazing disturbance studies to other range types in southwestern Idaho, including the subalpine grass-weed, the sagebrush-grass, and the mountain brush-grass range. There is also need for evaluating the effects of range improvement measures on runoff and sediment production from entire watersheds.

The watershed protection problem on forest land has thus far received but little attention. Much more effort on this problem is needed, especially for developing guides for tolerable limits of soil disturbance during logging in ponderosa pine stands.

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PUBLICATIONS OF THE INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

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PUBLICATIONS OF THE INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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Compiled by

Marguerite A. Israelson

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

Ogden, Utah

This list of publications of the Intermountain Forest and Range Experiment Station includes the most significant reports issued between 1912 and 1952. Publications have been grouped under the following general headings:

Forest Management and Silviculture	1	Wildlife Management	37
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Entries within each of these subjects are under the authors' names, which are in alphabetical order. The writings of each author are in chronological order with the most recent article last.

Publications marked with an asterisk (*) are not available for distribution. A variable supply, usually limited in number, of those not marked is available for distribution upon request. Journals and magazines cited may be consulted at most public and university libraries. Other publications such as Station Research Notes and Papers are on file and may be consulted at U. S. Department of Agriculture branch libraries (San Francisco, Albuquerque, and Missoula), agricultural college libraries, many other research libraries throughout the country, and at Forest Service experiment stations.

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2/ Earlier reports (1913-1929) were typewritten for in-Service use only. The reports from 1930-1939 were duplicated in small quantity and the supply is now exhausted. The Annual Reports from 1940 (except 1941) are available for distribution.

3/ The reports from 1913-1918 were issued under the name of "Utah Experiment Station;" from 1919-1929 as Great Basin Experiment Station;" and from 1930 to date as "Intermountain Forest and Range Experiment Station."

PUBLICATIONS

1956 THROUGH 1960

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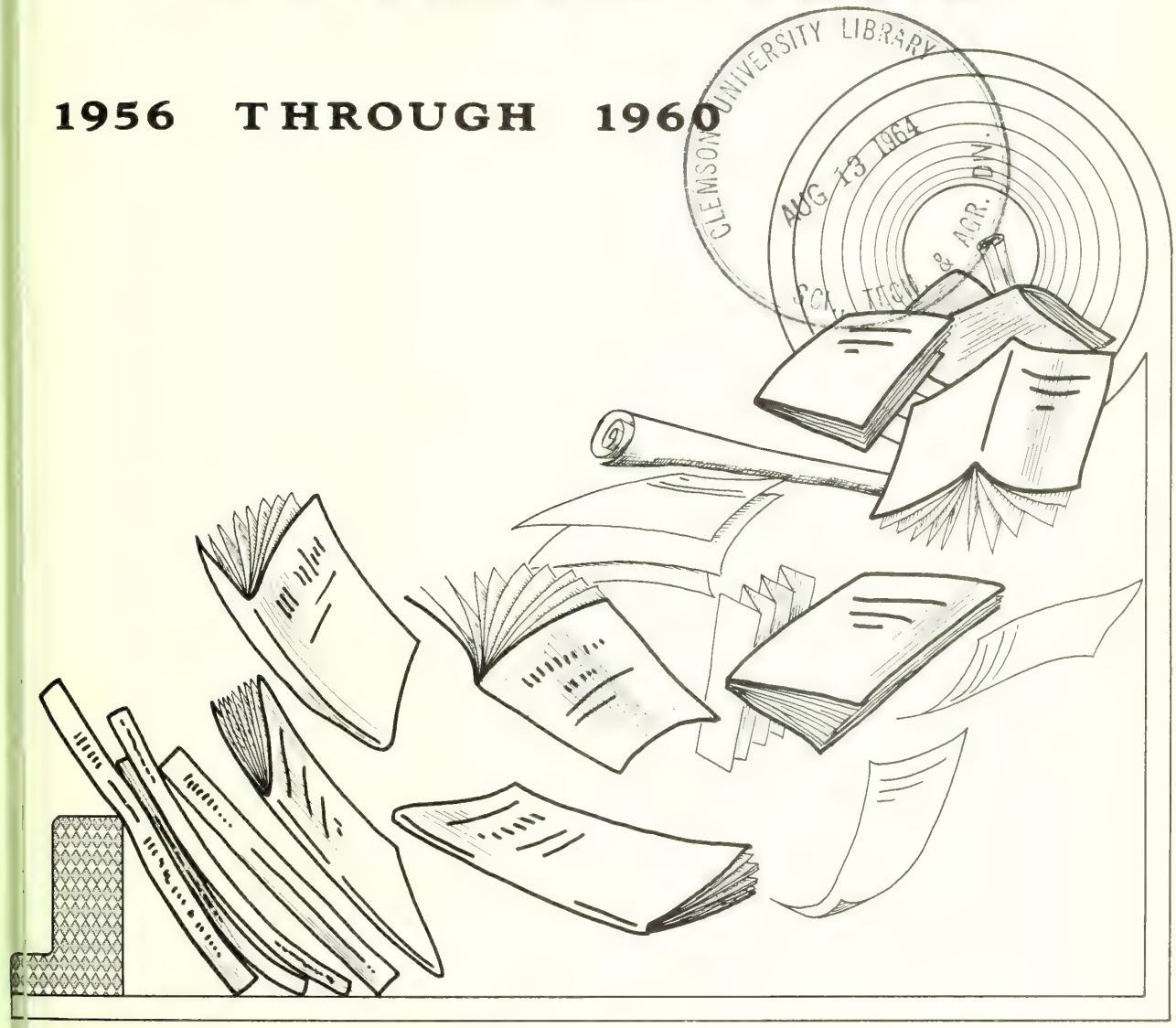

Intermountain Forest & Range Experiment Station
Forest Service
U.S. DEPARTMENT OF AGRICULTURE
Reed W. Bailey, Director

Research Paper No. 29 June 1961
(Supplement)

FOREWORD

All publications listed in this supplement have been issued by the Intermountain Station since 1955. Research Paper 29 and Supplement 1 report papers published through 1955.

The publications have been grouped under the following general headings:

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Forest Protection (Fire, Disease, and Insects)	9
Forest Survey (Photogrammetry)	23
Forest Utilization	25
Range Management	26
Watershed Management	30

Publications marked with an asterisk (*) are no longer available. Copies of others may be had upon request to the Director, Intermountain Forest and Range Experiment Station, Ogden, Utah, as long as supplies last. Forestry school libraries receive 5 copies of all station publications. Student requests for publications required for class use should be forwarded by the professor making the assignment.

Publications no longer available for distribution may be consulted at Department of Agriculture sublibraries, forest school and agricultural college libraries, many other research libraries throughout the country, and at Forest Service Experiment Stations.

P U B L I C A T I O N S

of the

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

1956 through 1960

Compiled by

Marguerite A. Israelson

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LODGEPOLE PINE BIBLIOGRAPHY

By

David Tackle and D. I. Crossley

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

THE NATURAL RANGE OF LODGEPOLE PINE

(From USDA Misc. Pub. No. 287, "The Distribution of Important Forest Trees of the United States" by E. N. Munns. April 1938.)

LODGEPOLE PINE BIBLIOGRAPHY

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INTRODUCTION

Lodgepole pine (Pinus contorta Dougl.) is a 2-needle pine of western North America with wide distribution and extremely variable growth habit. It occurs from Alaska south to Lower California and east to South Dakota. Botanically two environmental forms of this pine are recognized--a mountain form and a coastal form 1/. This bibliography is a compilation of published and unpublished literature on both forms of lodgepole pine.

The different scientific names for lodgepole pine appearing in the literature are primarily the result of early disagreement among taxonomists. The first technical name was based upon the stunted form growing along the lower Pacific slopes. This name, Pinus contorta Loudon, was first published in 1838. By various taxonomists the mountain form was considered first a separate species, then a variety of the coastal form, and finally an environmental form of the species. This mountain form, first described and named Pinus murrayana Balf. in 1853, is also, therefore, referred to in the literature as Pinus contorta var. murrayana Engel. and Pinus contorta var. latifolia S. Wats. Today the name Pinus contorta Dougl. is in common usage for both forms of this species, although some workers still hold to the "latifolia" variety when speaking of the mountain form.

Among the local names the following appear most frequently in the literature: "lodgepole pine," "shore pine," "sand pine," "scrub pine," "beach pine," "tamarac or tamarack pine," "pitch pine," "jack pine," and "Murray pine."

The bibliography, while not exhaustive, contains all the important reference material readily available to American and Canadian research workers. Some foreign literature is also included. In addition, many unpublished manuscripts and reports have been listed to provide persons searching for material with a knowledge of some of the more recent research on the species and as an aid in avoiding duplication when planning new research.

Subject Index

At the end of the bibliography there is presented a subject index. Each reference has been classified and is recorded by number under the principal subject with which it is concerned. Articles emphasizing two or three subjects have been appropriately

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1/ The mountain form is believed to have been discovered by Lewis and Clark in 1805 in the mountains above the headwaters of the Jefferson River in western Montana. The coastal form is said to have been discovered by David Douglas in 1825 near the mouth of the Columbia River in Washington.

cross-referenced. In no case does an article appear under more than three subjects, although some cover a broad field. Where a reference deals with many phases of a subject, it appears either directly opposite the main subject or opposite "General discussions" under the main subject. Articles from countries outside North America are found under "Foreign Publications."

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Several organizations and individuals assisted in the preparation of this bibliography. The authors wish to express their sincere appreciation to the School of Forestry, Yale University; Forestry Library, University of California; Northern Rocky Mountain Forest and Range Experiment Station; California Forest and Range Experiment Station; Rocky Mountain Forest and Range Experiment Station; Division of Bibliography, U. S. Department of Agriculture Library; and Forest Products Laboratory, U. S. Forest Service for reviewing the preliminary compilation of references and supplying additional titles. For many references and corrections received, special thanks are due Francis J. Flick, U. S. Department of Agriculture Library; Mary L. Eakin, Forestry Library, University of California; Dr. George S. Allen, Faculty of Forestry, University of British Columbia; Dr. E. A. Moss, Department of Botany, University of Alberta; George R. Hopping and Dr. V. J. Nordin, Laboratory of Forest Biology, Calgary, Alberta; Professor David M. Smith, School of Forestry, Yale University; Kenneth N. Boe, Northern Rocky Mountain Forest and Range Experiment Station; Russell K. LeBarron, California Forest and Range Experiment Station; and Jesse H. Buell, Rocky Mountain Forest and Range Experiment Station.

Helpful and constructive criticism by James D. Curtis of the Intermountain Forest and Range Experiment Station in the preparation of the Subject Index is gratefully acknowledged.

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STATISTICS ON WESTERN WILD LAND RESOURCES

Compiled by J. O. Lammi
Division of Forest Economics

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

Ogden, Utah

STATISTICS ON WESTERN WILD LAND RESOURCES

Compiled by J. O. Lammi
Division of Forest Economics

These statistics were compiled to make available in convenient form, facts which usually appear only in scattered publications and agency files. This paper revises and brings to date the tabulations which appeared as Research Paper No. 31, November 1953.

Whenever several sources of information are used to prepare statistical tables inconsistencies can develop, both within and between the tables. An effort was made to keep these to a minimum by careful selection of source and by cross checking. Nevertheless the users of these statistics should be on the alert for any discrepancies. These tables can be very helpful when used for general information, and as a guide to sources of more detailed data. If precise information is desired, special research should be done. Suggestions for improvement will be appreciated. Any errors should be called to our attention.

Current figures for many of the items presented in these tables may be secured from the agencies cited in the "source of data."

Source of data not otherwise cited is the U. S. Forest Service.

The following states and portions of states are included in Region 1 of the U. S. Forest Service (Northern Region): Idaho: Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, and Shoshone Counties; Montana: all; South Dakota: Butte and Harding Counties; Washington: Ferry, Lincoln, Pend Oreille, Spokane, Stevens, and Whitman Counties; Wyoming: the portion of Yellowstone Park east of the Continental Divide.

The following states and portions of states are included in Region 4 of the U. S. Forest Service (Intermountain Region): California: Alpine and Mono Counties; Colorado: the land area within the Colorado portion of the Manti-LaSal National Forest; Idaho: Ada, Adams, Bannock, Bear Lake, Bingham, Blaine, Boise, Bonneville, Butte, Camas, Canyon, Caribou, Cassia, Clark, Custer, Elmore, Franklin, Fremont, Gem, Gooding, Jefferson, Jerome, Lemhi, Lincoln, Madison, Minidoka, Oneida, Owyhee, Payette, Power, Teton, Twin Falls, Valley, and Washington Counties; Nevada: all; Utah: all; Wyoming: Lincoln, Sublette, Sweetwater, Teton, and Uinta Counties.

Some explanatory comments on the tables follow:

Table 3, columns 5, 6, 8, and 9 include all recreationists and sportsmen.

Table 4 state totals show the game harvest for the 1953 fall hunting season and the game population remaining after this hunt. Although wild turkeys are reported by the U. S. Fish and Wildlife Service they are not included in table 4. National forest estimates are for the fiscal year ending June 30, 1953, and are therefore not exactly comparable to state estimates which are for the calendar year ending December 31, 1953. The area of fishing lakes includes both natural lakes and reservoirs. The 1953 figures on sportsmen using the national forests are given in numbers of individuals, unless otherwise noted, whereas in 1954 they are in number of visits so as to agree with the recreational visits estimates of table 3.

Table 5, column 2 includes land within grazing districts only. Public domain land outside grazing districts is included with other Federal lands in column 3. Columns 17 and 22 are the nearest approximation to "beef cattle" that can be estimated from Census figures. Some beef type heifers are thus excluded while some dairy bulls are counted. Current inventories of livestock are published in the report, "Livestock and poultry on farms and ranches, January 1" issued annually in February by the Crop Reporting Board of the U. S. Agricultural Marketing Service.

Table 6, column 1 varies somewhat from other published figures. Although compiled by the U. S. Bureau of the Census the figures differ slightly from the acreage shown in the 1950 Census of Agriculture. The acreages are exclusive of water areas within the various states. Column 2 is "net" national forest acreage, thus excluding private, state, county, municipal, and some Federal ownership within national forest boundaries. Column 7, the total land area in U. S. Forest Service regions, is an estimate of the actual area rather than a summation of county areas.

Table 1.--Water resource

Western States

State	1	2	3	4	5
	Irrigated land	Irrigation water from all sources	Investment in irrigation works and water rights	Water power	
				Developed	Undeveloped
	Thous.acres	Thous.A.ft.	Thous. dollars	Thous.KW	Thous.KW
Ariz.	979	3,754	137,575	982	3,291
Calif.	6,599	24,362	640,474	2,821	7,802
Colo.	2,944	10,795	163,296	145	1,706
Idaho	2,168	22,226	129,974	637	8,097
Mont.	1,809	5,650	81,257	604	6,311
Nevada	723	1,578	20,181	587	111
N. M.	691	2,178	61,138	25	209
Oregon	1,338	5,228	74,361	816	6,460
Utah	1,167	5,409	56,539	94	1,215
Wash.	618	5,278	178,290	3,176	16,246
Wyoming	1,475	8,479	59,986	107	955
Total	20,511	94,937	1,603,071	9,994	52,403
Date and source	1949(6)	1949(8)	1/1/50(8)	Dec. 1952(6)	Jan. 1953(6)

Table 1.--Water resource (continued)

U. S. Forest Service Regions

State	6 Irrigated land	7 Irrigation water from all sources	8 Investment in irrigation works and water rights	9 National forest water production
	Thous.acres	Thous.A.ft.	Thous.dollars	Thous.A.ft./yr.
Region 1				
Idaho	8	99	2,970	
Mont.	1,809	5,650	81,257	
S. Dak.	56	157	4,609	
Wash.	21	109	3,308	
Wyoming	0	0	0	
Total	1,894	6,015	92,144	
Date and source	1949(8)	1949(8)	1949(8)	
Region 4				
Calif.	51	246	291	1/
Colo.	0	0	0	2/
Idaho	2,160	22,127	127,004	13,100
Nevada	723	1,578	20,181	900
Utah	1,167	5,409	56,539	4,600
Wyoming	368	3,600	4,601	6,300
Total	4,469	32,960	208,616	24,900
Date and source	1949(7)	1949(8)	1/1/50(8)	1953(16)

1/ Included with Nevada

2/ Included with Utah

Table 2.--Timber resource

Western States

State	1	2	3	4	5	6
	Total forest land	Commercial forest				
		Total	Federal ownership [1]	All other ownerships	Sawtimber volume all owners	Growing stock all owners
	Thousand acres				Million bd. ft. Intl.1/4"	Million cu. ft.
Ariz.	19,212	3,180	3,021	159	19,988	3,700
Calif.	42,541	17,317	9,070	8,247	360,001	66,411
Colo.	20,834	8,451	6,668	1,783	25,394	8,037
Idaho	21,025	13,372	9,579	3,793	96,015	21,246
Mont.	22,330	15,727	10,187	5,540	55,770	16,143
Nevada	12,036	109	32	77	572	151
N. M.	21,329	5,735	3,839	1,896	15,054	3,683
Oregon	2/29,387	2/26,330	2/15,251	2/11,079	2/381,389	2/85,213
Utah	16,219	3,014	2,566	448	7,800	2,001
Wash.	2/23,268	2/19,874	2/7,761	2/12,113	2/249,505	2/60,666
Wyoming	10,513	3,492	2,992	500	12,089	4,081
Total	238,694	116,601	70,966	45,635	1,223,577	271,332
Date and source	3/1952	3/1952	3/1952	3/1952	3/1952	3/1952

1/ May include small areas managed but not owned, e.g., tribal lands.

2/ National Lumber Manufacturers Association. 1953. Lumber Industry Facts.

3/ Published and unpublished Forest Survey data except as noted.

Table 2.--Timber resource (continued)

U. S. Forest Service Regions

State	7 :Comm.for. : land on :natl.for.	8 :Sawtimber :volume on :natl.for.	9 :Growing :stock on :natl.for.	10 :Comm.for. : land : private	11 :Sawtimber : volume : private	12 :Growing : stock :private
	Thous.A.	Million bd. ft. Intl.1/4"	Million cu. ft.	Thous.A.	Million bd. ft. Intl.1/4"	Million cu. ft.
			Region 1			
Idaho[1/]	4,418	33,333	7,403	2,475	18,871	4,061
Mont.	8,939	32,954	9,941	4,857	16,633	4,571
S. D.[1/]	18	4	3	30	7	4
Wash.[1/]	1,014	4,593	1,138	1,770	5,043	1,606
Wyoming[1/]	0	0	0	0	0	0
Total	14,389	70,884	18,485	9,132	40,554	10,242
			Region 4			
Calif.[2/]	58	[3/]377	75	Unavailable		
Colo.[2/]	5	21	5	Unavailable		
Idaho[2/]	4,756	29,887	6,881	492	2,821	609
Nevada	30	87	38	77	483	113
Utah	1,865	5,461	1,407	392	640	189
Wyoming[2/]	732	3,252	990	38	147	48
Total	7,446	39,085	9,396			
Date and source	[4/]1952	[4/]1952	[4/]1952			

1/ Parts of states, Region 1 portion.

2/ Parts of states, Region 4 portion.

3/ Scribner Decimal C log scale. All other volumes are International 1/4" rule.

4/ Published and unpublished Forest Survey data.

Table 2.--Timber resource (continued)

Western States

State	13 Lumber production	14 Active sawmills	15 Employees woods and plant	16 Value farm forest products sold
	Million bd. ft.	Number		Thous. dollars
Ariz.	247	61	2,030	712
Calif.	3,971	884	25,550	1,785
Colo.	153	403	2,860	290
Idaho	1,104	388	7,410	867
Mont.	598	1/434	2,890	643
Nevada	2/	2/	80	2
N. M.	125	162	1,560	183
Oregon	7,842	1,466	54,580	6,368
Utah	45	1,142	480	42
Wash.	3,660	808	54,280	3,580
Wyoming	58	170	1,370	132
Total	17,803	4,891	153,090	14,604
Date and source	1948(14)	1947(14)	7/1/44(14)	1949(7)

1/ Source: Hutchison, S. Blair, and Paul D. Kemp. Forest resources of Montana. U. S. Dept. of Agr. Forest Resource Report No. 5, 1952. Active sawmills as of 1948.

2/ Included with California

Table 2.--Timber resource (continued)

U. S. Forest Service Regions

State	17 National forest sawtimber cut: Volume	18 National forest sawtimber cut: Value	19 Value farm forest products sold
	Thous. bd.ft.	Thousand dollars	
Region 1			
Idaho	272,946	2,372	801
Mont.	319,989	1,838	643
S. Dak.	5	1/	0
Wash.	55,156	310	528
Wyoming	0	0	0
Total	648,096	4,520	1,972
Date and source	F. Y. ending 6/30/54		1949 (7)
Region 4			
Calif.	6,691	23	2/
Colo.	0	0	2/
Idaho	118,080	897	66
Nevada	255	1	2
Utah	40,830	224	42
Wyoming	13,170	58	4
Total	179,026	1,203	114
Date and source	F. Y. ending 6/30/54		1949 (7)

1/ Less than $500.00.

2/ Data not available.

Table 3.--Recreation resource

Western States

State	1	2	3	4	5	6
	Natl. parks and recr. areas 1/	State parks	Natl. forest wilderness 2/ areas	Recreational visits		
				Natl. parks	Natl. forests 3/	
	Thousand acres			Thousands		
Ariz.	1,445	15	734	2,008	1,025	1,253
Calif.	4,209	544	1,666	2,927	3,871	4,856
Colo.	518	0	1,523	1,193	2,148	3,395
Idaho	79	8	3,015	33	1,120	1,326
Mont.	1,141	3	1,924	390	832	1,104
Nevada	116	11	0	760	109	172
N. M.	235	3	940	651	560	1,332
Oregon	161	64	704	393	1,742	2,276
Utah	286	4/	241	599	2,786	2,983
Wash.	1,133	56	926	828	1,324	1,643
Wyoming	2,309	1	2,430	1,268	675	743
Total	11,632	705	14,103	11,050	16,192	21,083
Date and source	1950(1)	1950(1)	1949(2)	1949(12)	1949(18)	1952(18)

1/ Areas under the jurisdiction of the National Park Service.

2/ Includes variously classified as wilderness, wild, roadless.

3/ Not including people merely traveling through.

4/ Less than 500 acres.

Table 3.--Recreation resource (continued)

U. S. Forest Service Regions

State	7 : National forest wilderness areas	8 : National forest recreational visits	9
	Thous. acres	Thousands	
		Region 1	
Idaho	1,584	274	405
Mont.	1,984	2,500	3,814
S. Dak.	0	1/	11
Wash.	0	89	180
Wyoming	0	0	0
Total	3,568	2,863	4,410
Date and source	1951(17)	1949	1953
		Region 4	
Calif.	21	54	137
Colo.	0	1/	1
Idaho	1,434	904	1,174
Nevada	0	109	181
Utah	241	2,786	3,281
Wyoming	948	221	190
Total	2,644	4,074	4,964
Date and source	1949	1949	1953

1/ Data not available.

Table 4.--Wildlife resource

Western States

State	1	2	3	4	5	6
	Big game inventory					
	State total			National forest		
	Deer	Elk	Other	Deer	Elk	Other
	Thousands			Thousands		
Ariz.	255	1/7	37	84	1/11	24
Calif.	1,120	1	24	519	1	20
Colo.	300	50	23	227	35	12
Idaho	1/155	1/45	28	1/165	1/49	26
Mont.	270	47	85	177	35	21
Nevada	90	1/	8	84	1/1	1
N. M.	128	5	23	60	2	4
Oregon	577	35	20	205	31	9
Utah	350	5	2	213	5	1
Wash.	340	30	45	96	18	17
Wyoming	121	1/37	115	61	1/39	10
Total	3,706	262	410	1,891	227	145
Date and source	1953(13)			F. Y. ending 6/30/53		

1/ Discrepancy between state and national forest figures not explained, except insofar as state totals are after the hunting season whereas national forest (fiscal year) figures are before the hunting season.

Table 4.--Wildlife resource (continued)

U. S. Forest Service Regions

State	7	8	9	10	11	12
	National forest big game inventory					
	Deer	Elk	Other	Deer	Elk	Other
	Thousands			Thousands		
Region 1						
Idaho	40	26	7	41	32	8
Mont.	177	35	21	183	38	24
S. Dak.	1	-1/	3	-	-	-
Wash.	16	-	1	21	-	1
Wyoming	-	-	-	0	0	0
Total	234	61	32	245	70	33
Date and source	F. Y. ending 6/30/53			F. Y. ending 6/30/54		
Region 4						
Calif.	27	-	-	30	0	-
Colo.	1	-	-	1	-	-
Idaho	126	23	19	120	25	17
Nevada	84	1	1	92	1	1
Utah	213	5	1	221	5	1
Wyoming	13	25	5	16	25	5
Total	464	54	26	480	56	24
Date and source	F. Y. ending 6/30/53			F. Y. ending 6/30/54		

1/ Dash (-) in this table indicates data not available.

Table 4.--Wildlife resource (continued)

Western States

State	13	14	15	16	17	18
	Big game harvest					
	State total			National forest		
	Deer	Elk	Other	Deer	Elk	Other
	Number			Number		
Ariz.	19,121	1,558	3,527	9,600	1,100	1,560
Calif.	60,780	0	6,400	28,000	0	1,250
Colo.	72,375	5,299	4,836	40,000	3,100	730
Idaho	28,076	9,088	1,376	25,000	7,400	1,760
Mont.	80,000	13,000	22,667	20,000	5,000	1,300
Nevada	24,000	0	148	10,000	0	0
N. M.	16,370	225	1,068	5,400	50	170
Oregon	105,701	4,145	1,181	38,000	2,700	810
Utah	94,003	967	0	64,000	1,200	40
Wash.	72,000	2,700	8,150	9,900	2,200	1,190
Wyoming	46,056	9,826	35,740	18,000	8,100	820
Total	618,482	46,808	85,093	267,900	30,850	9,630
Date and source		1953(13)			F. Y. ending 6/30/53	

Table 4.--Wildlife resource (continued)

U. S. Forest Service Regions

State	19	20	21	22	23	24
	National forest big game harvest					
	Deer	Elk	Other	Deer	Elk	Other
	Number			Number		
Region 1						
Idaho	3,000	3,000	500	4,600	5,100	300
Mont.	12,300	7,100	600	23,600	6,200	2,200
S. Dak.	2/	2/	2/	2/	2/	2/
Wash.	1,920	14	80	3,500	100	200
Wyoming	0	0	0	0	0	0
Total	17,220	10,114	1,180	31,700	11,400	2,700
Date and source	F. Y. ending 6/30/51 1/			F. Y. ending 6/30/54		
Region 4						
Calif.	2,930	0	15	3,135	0	50
Colo.	250	0	0	350	0	1
Idaho	21,030	2,600	1,150	18,020	3,300	1,270
Nevada	10,000	0	0	9,300	0	0
Utah	64,000	1,200	40	69,000	870	40
Wyoming	3,200	5,200	590	3,600	6,000	649
Total	101,410	9,000	1,795	99,805	10,170	2,010
Date and source	F. Y. ending 6/30/53			F. Y. ending 6/30/54		

1/ Not available by states for 1953. The 1953 regional totals were: deer 28,000, elk 9,800, and other 3,180.

2/ Data not available.

Table 4.--Wildlife resource (continued)

Western States

State	25	26	27	28
	Sportsmen using national forests		National forest	
	Hunters	Fishermen	Fishing streams	Fishing lakes
	Number of individuals		Miles	Acres
	Thousands			
Ariz.	69	141	731	37,506
Calif.	462	597	12,173	130,703
Colo.	110	300	8,304	27,573
Idaho	125	266	10,352	151,115
Mont.	176	256	8,450	56,008
Nevada	21	30	1,061	215
N. M.	38	69	524	270
Oregon	161	394	6,325	53,907
Utah	102	100	2,472	18,790
Wash.	120	434	4,924	93,538
Wyoming	58	157	4,279	46,414
Total	1,442	2,744	59,595	616,039
Date and source	F. Y. ending 6/30/53		1953(6)	

Table 4.--Wildlife resource (continued)

U. S. Forest Service Regions

State	29	30	31	32	33	34
	Sportsmen in national forests				National forest	
	Hunters	Fishermen	Hunters	Fishermen	Fishing streams	Fishing lakes
	Number of individuals				Miles	Acres
	Thousands					
Region 1						
Idaho	1/	1/	45	92	4,408	124,904
Mont.	1/	1/	198	277	8,450	56,008
S. Dak.	1/	1/	- 3/	-	0	0
Wash.	1/	1/	17	47	436	3,955
Wyoming	0	0	0	0	-	-
Total	236	389	260	416	13,294	184,867
Date and source	F. Y. ending 6/30/53		F. Y. ending 6/30/54		1951(17)	
Region 4						
	Number of visits 2/					
Calif.	21	33	42	41	375	3,215
Colo.	-	-	-	1	7	50
Idaho	83	180	99	391	5,944	50,073
Nevada	21	29	21	21	1,061	283
Utah	102	100	165	463	2,472	28,813
Wyoming	21	57	31	50	1,431	64,480
Total	248	399	358	967	11,290	146,914
Date and source	F. Y. ending 6/30/53		F. Y. ending 6/30/54		1954	1954

1/ Estimates by states not available.

2/ Reported by visits rather than individuals as in Region 1.

3/ Dash (-) in this table indicates data not available.

Table 5.--Livestock forage resource

Western States

State	1	2	3	4	5
	Area open to grazing			No. of sheep[1] permitted	
	National forest	Grazing district	Other Federal	National forest	Grazing district
	Thousand acres			Thousands	
Ariz.	9,317	11,416	20,809	90	52
Calif.	8,868	2,904	13,405	119	117
Colo.	7,969	7,987	1,337	592	763
Idaho	9,397	12,381	1,068	626	1,054
Mont.	5,498	6,787	6,968	248	618
Nevada	3,847	32,203	13,719	133	625
N. M.	6,607	16,323	6,936	90	647
Oregon	8,092	12,377	2,766	148	206
Utah	5,657	23,866	2,741	477	1,378
Wash.	2,202	0	2,654	39	0
Wyoming	4,278	14,737	5,011	423	1,162
Total	71,732	140,921	77,414	2,985	6,622
Date and source	1947(11)	1947(11)	1947(11)	1952	1949(11)

1/ Includes some goats. Permitted number usually exceeds the number actually grazed.

Table 5.--Livestock forage resource (continued)

Western States

State	6	7	8	9	10	11
	No. cattle[1] permitted		Animal unit month		Animal unit month	
	National forest	Grazing district	sheep[2] permitted		cattle[1] permitted	
			National forest	Grazing district	National forest	Grazing district
	Thousands					
Ariz.	136	75	69	54	1,219	524
Calif.	103	99	92	82	471	403
Colo.	150	187	328	433	706	527
Idaho	109	261	371	543	498	910
Mont.	114	402	111	245	505	710
Nevada	56	348	97	592	242	1,724
N. M.	73	254	110	799	674	1,459
Oregon	70	278	112	123	331	1,027
Utah	108	207	292	1,350	499	1,112
Wash.	19	0	28	0	91	0
Wyoming	104	198	181	1,069	401	787
Total	1,042	2,309	1,791	5,290	5,637	9,183
Date and source	1952(18)	1949(11)	1949(11)	1949(11)	1949(11)	1949(11)

1/ Includes some horses. Permitted number usually exceeds number actually grazed.

2/ Includes some goats. An animal unit is 1 cow or 5 sheep.

Table 5.--Livestock forage resource (continued)

U. S. Forest Service Regions

State	12 : Natl. for. area open to grazing	13 : Number of sheep permitted on natl. for.	14 : Number of cattle permitted on natl. for.	15 : Animal unit month sheep permitted on natl. for.	16 : Animal unit month cattle permitted on natl. for.
	Thous. A.	T h o u s a n d s			
			Region 1		
Idaho	1,295	18	14	90	63
Mont.	5,033	248	118	486	502
S. Dak.	74	1/	4	1	53
Wash.	366	6	6	18	23
Wyoming	0	0	0	0	0
Total	6,768	272	142	595	647
Date and source	1953	1953	1953	1953	1953
			Region 4		
Calif.	512	28	6	18	20
Colo.	23	0	1	0	3
Idaho	5,660	608	98	361	397
Nevada	2,945	133	56	91	234
Utah	4,125	477	111	276	479
Wyoming	1,424	190	44	87	157
Total	14,689	1,436	316	833	1,290
Date and source	1953	1952	1953	1953	1953

1/ Data not available.

Table 5.--Livestock forage resource (continued)

Western States

State	17	18	19	20	21
	Livestock on farms 4/1/50		Value of livestock sold alive		
	Beef cattle[1]	Sheep[2]	Cattle and calves	Sheep and lambs	Value of wool shorn
	Thousands		Thousand dollars		
Ariz.	421	329	49,816	2,738	846
Calif.	1,108	1,227	229,976	24,462	5,653
Colo.	1,007	1,261	164,984	28,843	4,886
Idaho	423	834	59,905	18,480	3,741
Mont.	1,088	1,154	115,515	18,712	6,218
Nevada	286	272	21,510	2,661	1,205
N. M.	693	1,037	60,756	8,743	4,449
Oregon	507	555	53,316	7,872	2,250
Utah	282	991	30,394	12,949	4,098
Wash.	295	207	41,059	4,335	939
Wyoming	654	1,599	58,642	17,697	7,016
Total	6,764	9,466	885,873	147,492	41,301
Date and source	1950(7)	1950(7)	1949(7)	1949(7)	1949(7)

1/ Calculated from Census data as follows: To the total number of cows, including heifers that have calved, add number of all steers and bulls, and then subtract number of milk cows.

2/ Sheep and lambs born before October 1, 1949.

Table 5.--Livestock forage resource (continued)

U. S. Forest Service Regions

State	22	23	24	25	26
	Livestock on farms 4/1/50		Value of livestock sold alive		Value of wool shorn
	Beef cattle	Sheep	Cattle and calves	Sheep and lambs	
	Thousands		Thousand dollars		
Region 1					
Idaho	49	16	5,913	254	61
Mont.	1,088	1,154	115,515	18,712	6,218
S. Dak.	39	162	4,626	2,504	857
Wash.	74	27	9,221	359	87
Wyoming	0	0	0	0	0
Total	1,250	1,359	135,275	21,829	7,223
Date and source	1950(7)	1950(7)	1949(7)	1949(7)	1949(7)
Region 4					
Calif.	6	13	877	253	67
Colo.	- 1/	-	-	-	-
Idaho	374	818	53,991	18,226	3,680
Nevada	286	272	21,510	2,661	1,205
Utah	282	991	30,394	12,949	4,098
Wyoming	83	326	6,424	2,892	1,374
Total	1,031	2,420	113,196	36,981	10,424
Date and source	1950(7)	1950(7)	1949(7)	1949(7)	1949(7)

1/ Dash (-) in this table indicates data not available.

Table 6.--Land resource and human population

Western States

State	1	2	3	4	5		6
	Land area	Forest Service[1/]	Other Federal-owned land	State-owned land	Human population		
					Total		Rural
	Thousand acres				Thousands		
Ariz.	72,691	11,480	39,263	9,940	750	905	334
Calif.	100,354	19,935	26,137	2,932	10,586	12,087	2,047
Colo.	66,539	13,718	11,388	3,181	1,325	1,456	494
Idaho	52,997	20,326	14,163	2,961	589	598	336
Mont.	93,642	18,532	17,775	5,498	591	618	333
Nevada	70,273	5,058	53,955	58	160	199	68
N. M.	77,767	9,364	25,727	11,503	681	756	339
Oregon	61,664	14,924	17,993	1,609	1,521	1,630	702
Utah	52,701	7,916	30,049	3,027	689	750	239
Wash.	42,865	9,688	5,701	2,942	2,379	2,520	876
Wyoming	62,404	9,134	24,158	3,647	291	317	146
Total	753,897	140,075	266,309	47,298	19,562	21,836	5,914
Date and source	1951(5)	1954(15)	1950(1)	1950(1)	1950(9)	1953(6)	1950(9)

1/ Includes all U. S.-owned land administered by the Forest Service; e.g., national forests, purchase units, experimental ranges, land utilization projects, shop sites.

Note: Area in grazing districts by states is given as of June 30, 1953 in (6).

Table 6.--Land resource and human population (continued)

U. S. Forest Service Regions

State	7 Total land area	8 Forest Service land	9 Human population Total	10 Rural
	Thousand acres		Thousands	
Region 1				
Idaho	12,567	6,861	143	87
Mont.	93,362	18,532	591	338
S. Dak.	2,223	233	10	7
Wash.	7,884	1,215	295	94
Wyoming	1,300	0	0	0
Total	117,336	26,841	1,039	526
Date and source	1954	1954(15)		
Region 4				
Calif.	2,401	630	2	2
Colo.	27	27	1/	1/
Idaho	40,430	13,465	446	249
Nevada	70,273	4,997	160	68
Utah	52,701	7,916	689	239
Wyoming	15,587	3,787	43	26
Total	181,419	30,822	1,340	584
Date and source	1954	1954(15)	1950(9)	

1/ Data not available.

Source of Data

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RESEARCH PAPER NO. 32

May 1954

A CONDITION GUIDE FOR ASPEN RANGES OF UTAH, NEVADA, SOUTHERN IDAHO, AND WESTERN WYOMING

By

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Ogden, Utah

A CONDITION GUIDE FOR ASPEN RANGES OF UTAH, NEVADA, SOUTHERN IDAHO, AND WESTERN WYOMING

By Walter R. Houston[1/]

Aspen, Populus tremuloides Michx., the most widespread deciduous tree of western United States, is one of the most prominent features of its native, high mountain habitat. Its conspicuous, relatively pure and single-aged stands, vivid green foliage in summer, bright yellow leaves in autumn, and distinctive white trunks at any season--all set it apart from the conifers and shrub communities which may surround it.

In Utah, Nevada, western Wyoming, and Idaho south of the Salmon River,[2/] the area of range dominated by aspen approximates 2,000,000 acres. The lower and upper elevational limits of the type rise from north to south, from approximately 5,500 and 8,000 feet in southern Idaho to 8,000 and 10,000 feet in southern Utah. The type usually occurs between the mountain brush or sagebrush on the lower side and the subalpine conifer on the upper.

The type is an important one in the economy of the region. Since it is one of the largest and most productive of the montane types, it is extensively used as a summer range, both for livestock and big game. It makes a considerable contribution to the regulation of streamflow, is also used for recreation, and furnishes some timber products, principally excelsior.

Although forage production on the aspen ranges throughout the region has been reduced far below its normally high potential, little soil erosion is apparent; and from many observations the indications are that these ranges probably could be more easily restored to their former condition than many of the adjacent ones.

Because of the importance of aspen ranges for grazing, range managers are particularly interested in recognizing condition and trend on them. As a basis for grazing management plans, the range manager must know the productive potential of the type, how near a particular range is to this potential, and whether the range is changing toward or away from it. The purpose of this publication is to furnish a guide that will enable the range manager to determine the condition of most aspen-type ranges in the Intermountain region. A discussion of trend will not be entered into here.

1/ Mr. Houston is now Range Conservationist, Agricultural Research Service, Miles City, Montana. This study was completed and the manuscript written while he was with the Intermountain Forest and Range Experiment Station.

2/ This area formerly defined the area of responsibility of the Intermountain Forest and Range Experiment Station, which has been enlarged since this was written. This restricted area is meant when "Intermountain region" or "region" is used in the present report.

A general treatment of the subject is presented in "Indicators of Condition and Trend on High Range Watersheds in the Intermountain Region" by Ellison, Croft, and Bailey (3).3/

This guide is based on examinations of all degrees of range condition over a 4-year period, 1949 to 1952. The ranges examined varied from some that had been ungrazed for 40 years to others that had been virtually denuded by long-continued overgrazing. Observations were made of species composition of ground cover vegetation, both of the aspen understory and adjacent openings, plant and litter cover, vegetal production, degree of erosion, and evidences of trend.

REVIEW OF LITERATURE

Several range condition and trend guides that consider the aspen type, among others, have previously been prepared for local areas of the Intermountain region. Two have been prepared by the administrative branch of the U. S. Forest Service, one for the Mono division of the Toiyabe National Forest in Nevada (15) and one for the Heise Ranger District of the Targhee National Forest in southeastern Idaho (14). Two such guides have been prepared by U. S. Soil Conservation Service technicians for the Bear Lake (4) and Yellowstone Soil Conservation Districts (10) of eastern Idaho. General guides to condition and trend of mountain range-watersheds of this region have been prepared by Ellison (2) and Ellison, Croft, and Bailey (3).

Sampson's early work in central Utah (9) indicated that moderate cattle use and very light sheep use of aspen ranges resulted in proper use of the aspen reproduction. Julander's investigations in Arizona (6) disclosed that aspen was a key forage species for deer summer range, that maximum allowable utilization of aspen reproduction was 70 to 75 percent, and that degree of utilization of aspen was an indicator of relative deer stocking. However, more recent research revealed that in central Utah, when more preferred forage is available, aspen may not be a reliable key species on deer range, and that often aspen utilization is not a sensitive guide to proper stocking (12). Marston's (7) work on soil protection requirements in northern Utah indicated that about a two-thirds cover of vegetation or litter is necessary to avoid excessive soil loss by summer storms.

CHARACTERISTICS OF THE ASPEN TYPE

Aspen stands vary widely in size. They may occur as islands of trees separated by openings of varying size, or as a more or less continuous forest. The term, aspen type, as used in this publication refers to all these areas. It includes not only the areas overshadowed by aspen, but also the openings in the aspen forest. It does not include areas of aspen mixed with more than 50 percent of conifer trees, however, or more than 50 percent of oak and maple.

3/ Figures in parentheses refer to Literature Cited, page 16.

An important characteristic of the aspen type is its very high production potential. Many sites produce 1,000 to 2,000 pounds per acre air-dry, and some as high as 5,000 pounds, of herbaceous and shrubby vegetation. The evidence at hand indicates that on ranges in good condition, the openings are fully as productive of forbs, grasses, and shrubs as the area beneath the aspen overstory.

Aspen Understory

The normal species composition of the understory, which may contain almost any proportion of grasses, forbs, and brush, varies considerably throughout the region. Although the dominance of a single species--aspen--suggests uniformity, some 300 understory species have been identified on aspen ranges and combinations of these 300 species are almost limitless. Species that are normally constituents of adjacent mountain brush, sagebrush, or lodgepole pine types are found in many aspen stands. Thus, where aspen grows near lodgepole stands, its understory vegetation may be dominated by the common dominant of the lodgepole understory, pinegrass, Calamagrostis rubescens. Although this grass is of low palatability, its dominance may be natural rather than induced by past overgrazing.

For most of the aspen ranges of the Intermountain region, however, the natural, undisturbed understory vegetation appears to have consisted chiefly of a mixture of many species of tall, succulent forbs and grasses. Among these the following were probably conspicuous:

Forbs:

Agastache urticifolia
Aquilegia coerulea
Aster engelmanni
Delphinium barbeyi
Heracleum lanatum
Mertensia leonardi
Osmorhiza occidentalis
Senecio serra
Thalictrum fendleri
Valeriana occidentalis

Grasses and sedges:

Agropyron trachycaulum
Bromus carinatus
Carex spp.
Elymus glaucus

The commonest shrubs were probably Symphoricarpus spp. and Pachistima myrsinites.

The understory of most aspen range has been greatly altered by years of overgrazing. As the palatable species were eliminated by close, repeated use, the change has been toward dominance by lower growing, more drought-resistant, and less palatable species. Severely depleted ranges are dominated by annuals, ruderals, and unpalatable perennials. These less desirable plants often afford little protection to the soil. Litter cover is lessened as the litter is pulverized and trampled, and the soil may be compacted with an attendant increase in soil erosion. In

time the canopy is opened by the continued destruction of aspen reproduction which may eventually result in conversion to a herbaceous type (fig. 1).

At present only a few ranges in good condition and a number of small scattered areas that have escaped severe grazing because of inaccessibility reveal the true potentiality of the aspen type. On ranges that are improving from a depleted condition, evidence of increase of the more palatable species listed above--Aster, Heracleum, Mertensia, Osmorhiza, Valeriana, grasses, and sedges--is usually to be found. It is important to remember that a mixed composition is desirable and natural for the aspen type. Dominance by a single species or very few species (see fig. 3) is usually a sign of overgrazing.

The aspen type is temporary, ecologically speaking, being brought into prominence by fire. Aspen will in time be succeeded by conifers, usually alpine fir, Engelmann spruce, Douglas-fir, or white fir.

Succession to conifers has a marked influence on site characteristics. The litter layer becomes deeper and different in character. Less light and moisture reach the lower levels of the stand because of greater interception by the conifer crowns. It is probable that consumptive use of soil moisture is substantially changed, although how it is changed is not yet known. Succession to conifers also results in a considerable lowering of the grazing capacity of the type by changes in species composition of the understory vegetation and lessening of production.

Aspen Openings

In the natural, ungrazed state, differences between the herbaceous vegetation of openings and understory are probably minor. Where material differences are found in species composition, vegetal and litter cover and soil compaction, they are probably related to a tendency for animals to concentrate in the openings. It is probable also that vegetation of the openings recovers more slowly than under the aspen canopy because of greater insolation and higher rate of evaporation.

For these reasons openings in the aspen type are considered the key areas. Key areas are defined as those parts of the range that carry the bulk of the grazing load, that are naturally grazed more heavily by livestock than the range as a whole, or that are particularly liable to damage by grazing and trampling. (Very small areas where livestock concentrate excessively, as on salt grounds, at fence corners, or near permanent water, are not to be considered key areas.) If the key areas can be so managed as to maintain their soil stability and forage productivity, and improve in condition, the less heavily grazed portions of the range and those less susceptible to damage may also be expected to improve.

CONDITION

Range condition has been defined as: "...range health; it is the relative position of a range with regard to a standard set up by

management objectives within the practicable potentialities of the site. Satisfactory condition requires vegetation both sufficiently dense to maintain soil stability and having a considerable proportion of choice forage species. Unsatisfactory condition involves either vegetation so sparse as to permit erosion rates greater than normal, or, if sufficiently dense to prevent erosion, a preponderance of undesirable species"(11).

Criteria of Condition

In this publication the gamut of aspen range condition is arbitrarily divided into five classes: excellent, good, fair, poor, and very poor--based on amount of cover, kind of vegetation, amount of total herbage production, degree of erosion, and presence or absence of aspen reproduction.

Cover

The higher percentages of plant and litter cover are directly associated with better range condition, and the lower percentages of cover with poorer range condition. Cover, as the term is used here, refers to the proportion of ground overshadowed by plants 5 feet or less in height, plus that proportion not overshadowed by plants but covered by litter. When the proportion of bare ground is added to these, the total is 100 percent. Since this concept of cover differs from some others commonly used, it will be well to describe in some detail how it is determined. These proportions are determined by viewing all components vertically, visualizing them as reduced to a flat plane on the ground surface, as if in a vertical photograph. The projection to the ground surface of each living plant part, no matter how small, or of each fragment of dead plant material not already covered by leafage, contributes to the respective totals of plant and litter cover. Similarly the openings between leaves and litter through which bare ground can be seen, no matter how minute these may be individually--and they are usually to be found even with very dense cover--are totaled to give the estimate of the proportion of bare ground. Usually there is a natural tendency to ignore openings where the cover is dense, and to ignore litter when it consists of scattered fragments where the ground is nearly bare, which must be guarded against. Objective training in estimating cover in accordance with this concept is provided by use of the point analyzer (1); such training helps overcome these errors of omission.

Species Composition

Species composition expresses the proportions of the various species of grasses, forbs, and shrubs that constitute the aspen understory or the vegetation of openings. It is determined in the same manner as plant or litter cover, that is, on the basis of projection of foliage. While plant cover is only one of the constituents of ground cover, it is regarded as 100 percent for the purpose of expressing species composition. Thus a certain area may be covered 45 percent by live vegetation, and perhaps 15 percent by litter, with the remainder bare ground, but the 45 percent is considered to be 100 percent of the species composition.

Then each species contributes a percentage toward this total of 100 percent.

For use as indicators the plant species are divided into five groups. It should be understood that these groups are somewhat arbitrary and that the individual species in a group characterizing a certain range condition class are not confined to that class but may also be found in others. Thus annuals may be found in small amounts on aspen range in good condition, and some of the more desirable plants may be found on range in poor condition. Some species may persist for years though conditions are no longer favorable for them; as Rudbeckia may persist as the range recovers from past misuse and Mertensia or Bromus carinatus even under overuse. Also several of the plants of Group 2--Agastache, Agropyron, Bromus, and Elymus--usually make up a considerable portion of the vegetation in excellent condition class, although they are most abundant in good condition class.

The species that are found on range in excellent to good condition, and that are practically absent from range in poor condition are all tall, succulent, highly palatable plants that usually disappear under heavy grazing. These plants, placed in Group 1, are:

Aconitum columbianum
Aster engelmanni
Delphinium spp. (tall)
Heracleum lanatum
Mertensia leonardi
Osmorhiza occidentalis
Polemonium foliosissimum
Valeriana occidentalis

The species most abundant on range in good to fair condition, placed in Group 2, are:

Forbs:

Agastache urticifolia
Aquilegia coerulea
Astragalus convallarius diversifolius
Balsamorhiza sagittata
Castilleja spp.
Crepis acuminata
Erigeron spp.
Galium boreale
Helianthella uniflora
Hackelia floribunda
Hedysarum spp.
Ligusticum porteri
Lupinus spp.
Phacelia heterophylla
Senecio serra
Smilacina stellata
Thalictrum fendleri
Trifolium spp.
Vicia americana
Viguiera multiflora

Grasses:

Agropyron subsecundum
Agropyron trachycaulum
Bromus carinatus
Carex spp.
Elymus glaucus
Festuca idahoensis
Festuca ovina
Hordeum spp.
Koeleria cristata
Melica spp.
Phleum alpinum
Poa spp. (tall)
Stipa columbiana

The species most abundant on range in fair to poor condition, placed in Group 3(fig. 5), are:

Forbs:

Aster spp. (except A. engelmanni
Agoseris spp.
Allium spp.
Delphinium spp. (low)
Fragaria spp.
Gentiana spp.
Geranium spp.
Hydrophyllum spp.
Lathyrus spp.
Osmorhiza obtusa
Penstemon spp.
Plantago tweedyi
Polemonium albiflorum
Potentilla spp.
Ranunculus spp.
Rudbeckia occidentalis
Rumex spp.
Senecio spp. (except S. serra)
Wyethia amplexicaulis
Valeriana edulis
Viola spp.

Grasses:

Festuca thurberi
Muhlenbergia montana
Poa spp. (low)
Trisetum spicatum

Shrubs:

Amelanchier spp.
Pachistima myrsinites
Populus tremuloides reproduction
Prunus spp.
Sambucus spp.
Salix spp.
Symphoricarpos spp.

The species most often found on range in very poor condition include mat-formers, those that normally occur on warm, dry sites, ruderals, annuals, and ephemeral species that dry up and so give little protection to the soil, and in general, plants of low palatability. These species (Group 4) are:

Annual species:

Amaranthus retroflexus
Chenopodium album
Collinsia tenella
Collomia linearis
Descurania incisa
Galium bifolium
Gayophytum ramosissimum
Lepidium densiflorum
Madia glomerata
Nemophila breviflora
Orthocarpus tolmiei
Polygonum douglasii

Rhizomatus species:

Achillea lanulosa
Artemisia discolor

Species of warm, dry sites:

Arabis spp.
Eriogonum heracleoides
Gilia aggregata
Stipa lettermani

Ruderal species:

Cirsium spp.
Lactuca scariola
Malva rotundifolia
Oenothera flava
Taraxacum officinale
Tragopogon pratensis

Others:

Artemisia spp. (woody)
Astragalus spp. (except A. convallarius diversifolius)
Chrysothamnus spp.
Frasera speciosa
Helenium hoopesii
Mahonia repens
Pteridium aquilinum
Rosa woodsii
Stellaria jamesiana
Urtica gracilis
Veratrum californicum

Several of the species encountered on aspen range seem to have no relation to any particular range condition, but occur as commonly on better as on poorer ranges. These species, and those for which there is insufficient information for more definite assignment, are included in Group 5:

Forbs:

Corallorrhiza spp.
Epilobium angustifolium
Lithophragma spp.
Scrophularia spp.
Thlaspi glaucum

Grass:

Calamagrostis rubescens

Shrubs:

Ribes spp.
Vaccinium spp.

It is difficult to use Groups 2 and 3 as indicators because their proportions first increase as range condition declines and then decrease as condition becomes poorer. For this reason Group 2 is used as an indicator only in conjunction with Group 1, and then only in the poorer condition classes, and Group 3 is not used in "very poor" condition class.

Aspen Reproduction

The presence or absence of aspen reproduction has long been used as an indicator of range condition. If aspen reproduction was present, the range was considered in satisfactory condition; if absent, in unsatisfactory condition. There are several factors other than grazing, however, that influence reproduction of aspen. It has been commonly observed that dense aspen stands usually produce few sprouts, while open stands usually produce many more. A recent study (13) showed that the presence of herbaceous and shrubby vegetation in and near aspen stands may have a definite effect on reducing aspen reproduction. Also another study (12) indicated that several species are more palatable than aspen sprouts, and the range could be overgrazed from the standpoint of these species without materially affecting the aspen. For these reasons the simple presence or absence of reproduction is not a reliable indicator of range condition. If little reproduction is present, and it can be determined

that its absence is due solely to grazing, then this absence is an indicator of unsatisfactory range condition If the absence of reproduction is not due to grazing, or abundant reproduction is present, then no particular condition class is indicated.

Production

While there is a tendency for high production to be associated with good range condition and low production with poor range condition, many exceptions will be found. Production in any one condition class, depending on the species composition, often varies as much as 600 to 2,200 pounds (air-dry) per acre. Species of different indicator groups--Agropyron, Bromus, Lathyrus, Rudbeckia, and Sambucus--are particularly productive and may influence total production greatly. For these reasons high total production may be misleading. Only low production is used here as an indicator. If production drops below 850 pounds per acre, condition is considered to be no better than "poor," and if it drops below 500 pounds, condition is indicated as "very poor."

Erosion

Observable evidence of erosion in the aspen type is used as an indicator of poor or very poor range condition. Slight erosion is defined as evidence of erosion that is apparent for only a short time--e.g., rill marks--and often occurs in patches, while marked erosion is defined as permanent evidence--e.g. pedestalled plants, gullies--over a considerable area. If observable traces of erosion are present the range can be no better than poor, but lack of erosion does not in itself indicate any condition class. Aspen understory range particularly may be in unsatisfactory condition with no apparent soil erosion.

A Guide to Condition Classification

In table 1 the five condition classes are set against eight indicators of condition. In appraising condition on a particular area, each indicator is considered in turn and, insofar as it applies, a tentative condition class is derived from it. Under some circumstances different indicators will indicate different tentative classes. When this occurs, the final judgment is the lowest condition class indicated. It is believed that sounder judgment of range condition can be achieved in this way than by "averaging" tentative classes.

Though the openings are usually key areas in the aspen type, it is desirable to make observations in the understory as well. On large areas of continuous aspen forest the key areas may be understory. Furthermore the first signs of range improvement usually show up in the understory, sometimes far in advance of their appearance in the openings. In any event a blanket rule will not do: observations need to be made on each range to determine the key areas.

Table 1 --Guide for use of aspen range condition indicators in the Intermountain region

Indicator	Condition class				
	Excellent	Good	Fair	Poor	Very poor
1. Group 1 species, percent	50-100	25-49	25-100	Less than 25	Less than 25
2. Group 2 species, percent	1/--	--	25-100	Less than 25	Less than 25
3. Group 3 species, percent	0-10	11-25	26-45	46-100	--
4. Group 4 species, percent	0-5	6-15	16-35	36-54	55-100
5. Cover, percent (vegetation plus litter)	90-100	75-89	55-74	40-54	0-39
6. Presence of aspen reproduction	--	--	--	Absent, due to grazing	Absent, due to grazing
7. Erosion	--	--	--	Slight	Marked
8. Production, lbs. per acre, air-dry	850+	850+	850+	500-850	0-500

1/ Blank indicates that a particular indicator is not used in that condition class

To illustrate the use of the condition guide and its application to key openings as well as to understory, adjacent aspen opening and understory ranges actually encountered in the field during the course of this study will be described (table 2).

Area X

The aspen understory at this site has a very high proportion of Group 1 species, moderate amounts of Group 2 and 3 species, and only a small amount of Group 4. Referring to table 1, it is evident that species of Groups 1 and 4 indicate "excellent" condition while species of Group 3 indicate "good." On this range two-thirds of the ground surface is covered with vegetation and, when litter is combined with this, the ground cover is almost complete, indicating a condition class of "excellent." Since production amounts to almost a ton per acre, no erosion is evident, and some aspen reproduction is present, there is no indication of "poor" or "very poor" condition. In view of the rule of conservative

classification, the final condition class indicated is "good." Figure 2 is a photograph of this site.

Table 2.--Plant composition, cover, and production, degree of erosion, and presence of aspen reproduction in three aspen understory stands and openings adjacent to them

Indicator	Area X		Area Y		Area Z	
	Understory	Open	Understory	Open	Understory	Open
	Percent		Percent		Percent	
Species Composition						
Group 1						
Delphinium barbeyi	1	-	-	-	-	-
Heracleum lanatum	40	7	-	-	-	-
Mertensia leonardi	6	20	-	-	-	-
Osmorhiza occidentalis	7	12	-	-	-	-
Polemonium foliosissimum	2	-	-	-	-	-
Total	56	39	-	-	-	-
Group 2						
Agastache urticifolia	3	7	-	-	-	-
Agropyron trachycaulum	T	T	2	3	-	-
Bromus carinatus	T	26	3	3	3	2
Carex spp.	-	-	2	2	-	-
Erigeron speciosus	-	-	13	9	-	-
Galium boreale	-	-	-	4	-	-
Lupinus spp.	-	-	7	-	-	-
Senecio serra	-	-	-	1	-	-
Smilacina stellata	-	-	T	1	-	-
Thalictrum fendleri	6	2	T	5	-	-
Stipa columbiana	-	-	2	3	-	-
Vicia americana	1	6	3	T	3	2
Viguiera multiflora	-	2	-	1	-	-
Total	10	43	34	33	6	4
Group 3						
Agoseris pumila	-	-	T	1	-	-
Geranium spp.	-	-	5	12	4	-
Lathyrus leucanthus	2	1	-	-	T	-
Osmorhiza obtusa	1	T	T	-	5	T
Penstemon spp.	-	-	3	23	-	-
Potentilla spp.	-	-	T	2	-	-
Rudbeckia occidentalis	-	-	30	6	8	28
Rumex mexicanus	-	-	-	-	-	4
Sambucus spp.	T	13	-	-	-	-
Symphoricarpos spp.	16	-	T	T	41	1
Poa pratensis	-	-	2	1	T	5
Viola spp.	3	-	-	-	6	8
Total	22	14	42	45	64	46

Table 2. (Continued)

Indicator	Area X		Area Y		Area Z	
	Understory	Open	Understory	Open	Understory	Open
	Percent		Percent		Percent	
Group 4						
Achillea lanulosa	-	-	3	3	T	T
Artemisia discolor	-	T	-	5	-	-
Chenopodium album	-	1	T	-	1	4
Collomia linearis	-	T	4	2	2	7
Galium bifolium	T	T	2	-	2	2
Helenium hoopesii	-	-	-	-	T	3
Polygonum douglasii	-	-	T	-	T	4
Stellaria jamesiana	2	1	T	2	2	2
Taraxacum officinale	T	T	14	7	20	26
Total	2	2	23	19	27	48
Group 5	8	-	-	-	T	-
Cover						
Vegetation	68	76	57	54	44	30
Litter	26	15	26	26	27	20
Total	94	91	83	80	71	50
Production (lbs. per acre, air-dry)	1,960	4,150	1,200	1,850	1,480	670
Degree of erosion	None	None	None	None	None	None
Presence of aspen reproduction	Present in moderate amount	--	Present in moderate amount	--	Absent due to grazing	--

Most of the species of the nearby openings are about evenly divided between Groups 1 and 2, with a small amount of Group 3 species and almost none of Group 4. The proportions of both Group 1 and 3 indicate "good," and of Group 4 "excellent," condition. The high total cover also indicates "excellent" condition. Again, the factors of production and erosion suggest that condition is neither "poor" nor "very poor." The final condition class indicated, with the choice between "excellent" and "good," is "good." Figure 4 shows an aspen opening in good condition.

Area Y

A large proportion of the species of the understory stand here fall in Groups 2 and 3, with a smaller amount of Group 4 and no Group 1 species present. The percentage figures in table 1 for these indicators

place the stand tentatively in "fair" condition and the high total cover in "good" condition. Since production is above 850 pounds per acre, aspen reproduction is present in moderate amount, and no erosion is evident, condition is probably neither "poor" nor "very poor." The conclusion, then, based on the lowest tentative condition class indicated, is that this understory range is in "fair" condition.

The species composition of the opening is very similar to that of the understory, but includes a slightly smaller proportion of Group 4 species. The composition percentages indicate "fair" condition. The total cover of this opening also is very similar to that of the adjacent aspen understory stand, and indicates "good." As with the understory stand, production is great enough, and erosion inconspicuous enough, to keep this opening out of the "poor" condition class. Adopting the lowest tentative value, this opening is concluded to be in "fair" condition.

A comparison of the opening and understory stand here reveals very little difference, except a somewhat greater production in the opening. Figures 5 and 6 are photographs of these sites.

Area Z

The indicator species of the understory stand fall most in Groups 3 and 4, very few in Group 2, and none in Group 1. The proportion of Group 3 species indicates "poor," and of Group 4, "fair" condition. As there is less than 25 percent of species in Groups 1 and 2, "poor" or worse is indicated. The almost three-quarters total cover indicates "fair" condition. There is fairly high production, and no evident erosion on the site, indicating neither "poor" nor "very poor." The absence of aspen reproduction here, which from the evidence of utilization is known to be due to grazing, indicates "poor" condition at most. Although several of the factors indicate "fair" condition, the lowest class indicated--on the basis of the proportions of Group 1, 2, and 3 species and the absence of aspen reproduction--is "poor," and this should be the judgment for this aspen understory range.

The opening includes an even higher percentage of Group 4 species than the understory. Both because of the scarcity of Group 1 and Group 2 species and because of the abundance of Group 3 and 4 species, this stand is rated tentatively as "poor." About one-third of the ground surface is covered by foliage, and litter between the plants is abundant enough to bring the total ground cover up to 50 percent, indicating "poor" condition. Production on this site, which is only half as great as on the nearby understory site, likewise rates "poor." The fact that no evidence of erosion was noted probably relates to the fact that no torrential storms had occurred during the summer in which the site was examined. All the indicators point to the conclusion that the final rating here is "poor." Figures 7 and 8 show aspen understory and an aspen opening in poor condition.

Procedure in Judging Range Condition

Because it is difficult to reconstruct vegetation accurately after even moderate utilization, and almost impossible after heavy, the best time to make the inventory is necessarily after vegetation has reached full growth but before the area is grazed, or at least before grazing has materially obscured species composition. However, since the primary reason for the use of plant cover as an indicator of condition is its soil-protective function, and since cover is naturally least at the end of the grazing season, provision should be made to examine the range at a later date also, possibly in connection with observations on utilization, to note how fully vegetation is permitted to protect the soil.

In judging range condition the range manager must select an area for sampling which is reasonably representative of the grazing unit to be judged. Usually an open area within the aspen stand, or an opening at its edge, will be selected as the key area. Cover, plant composition, erosion, indicators of trends, and sometimes production, are to be observed.

To make the observations, a series of small plots is laid out along a transect in the key area. The plots may be spaced at mechanical intervals by pacing or chaining, and may be marked to aid in relocation. In any event the individual plots should not be consciously selected.

The plots should be small enough to be taken in at a glance--a square or circular plot of 9.6 square feet is a convenient size for determining both cover and production. A central hub can be used with radius rods to define a circular plot, four willow sticks can be used to outline a square plot, or a wire hoop can be used.

Ordinarily 20 plots will give a reliable estimate of cover, although in some instances 10 may be enough. The same number, at least, will be needed for estimates of production, if such estimates are to be made. Twenty plots will ordinarily give a good idea as to the proportions of the major species in the stand, but they must be supplemented by observations on the stand as a whole for scarce species and for indicators of erosion and of vegetal trend. The variations in results between plots, and the extent to which the average becomes more stable as plots are added, are the best guides to the number of plots needed in each case.

In estimating cover, as already pointed out, care should be taken to prevent bias so that no one of the elements of bare ground, litter, and living plant material will be favored over others. The observer must balance these three values in his mind as he looks down. His mental processes are fluid as he considers them, and may be something like this: "There is a lot of bare ground on this plot--say 50 percent. There is more leafage than litter--say 30 percent leafage and 20 percent litter. No, when one considers the scattered grass stems on that seemingly bare area, litter should come up to about the same as leafage--make them 30 and 30. Then we must bring bare ground down to 40 percent. Forty, 30 and 30--yes: there's about a third more bare ground than either

leafage or litter, those two are about equal, and together they cover about half as much surface again as the bare ground." Such estimates, after a little practice, can be made rapidly, although one must be alert continually against bias, either in favor of vegetation, bare ground, or litter. If bias can be minimized, a sounder average will be obtained from approximate estimates on many plots than from very precise estimates on only a few plots.

On these same plots, estimates of vegetal composition should be made for all species. Then percent composition for each plot can be balanced in the observer's mind, just as cover values are, to arrive at a total of 100 percent. The names of other species having indicator value encountered off the plots should also be listed, but no percentages are assigned to them.

When all the plots have been examined, the observer averages the percentages for the abundant species, and these averages provide a basis for the estimate of percentage composition of these species in the stand as a whole. Those species that make up less than half of one percent are marked "T" for "trace," and often when such species are numerous, a percentage must be assigned to the total of "T's." After arriving at these percentage figures it is advisable to walk back through the stand, weighing and judging them by simple observation. If the estimates are obviously wrong in any respect, it will be necessary to correct them by supplementing the plots with another series.

Observations on erosion should not be confined to the sample plots. One must be alert over the entire range to observe such indicators as bare areas, trampling displacement, pedestalling of grasses, rill marks, blowouts, and gullies, active or healed. Similarly, observations on vegetal trend must extend beyond the sample plots. Indicators to be watched for particularly are age-class distributions, accessibility of palatable species, hedging of shrubs, and excessive utilization of aspen reproduction. These indicators of condition and trend are described elsewhere (3).

Insofar as using this guide is concerned, there is no need to estimate production unless one wishes to distinguish "fair" from "poor," or "poor" from "very poor" condition. Indeed, although estimates of production are desirable, and are sometimes of great help in arriving at decisions about grazing capacity, it cannot be said categorically that they are essential.

An appraisal of production may be made in one of two ways, either by clipping all the herbage from carefully measured plots and weighing, or by estimating weight after intensive training in weight estimation (5, 8). With either, the work should be done when the vegetation is at the height of its development, preferably before utilization has taken place. If some vegetation has been utilized, an estimate of the amount removed needs to be added to the production values. In either case, too, samples of the vegetation, preferably of each species, must be air-dried to provide correction for moisture content.

Finally, a word should be said about records. Much work is wasted because the observer was in too great a hurry to write out a full account of what he saw. The information he collects should be neatly recorded, fully labeled, with dates, names, places, and units of measurement explained, and carefully preserved, so that the facts can be reconstructed at a later time, either by himself or someone else. The study areas should be permanently marked in the field and described in the notes so that they can be relocated easily. One of the best ways of describing locations is by marking them on a map, if a map of 2 inches to the mile or larger scale is available. The individual plots need not be permanently marked, although if they can be, so much the better. If they are not marked, the direction of the transect line along which they are laid should be given, and its limits should be stated: this will insure sampling the same area on later visits.

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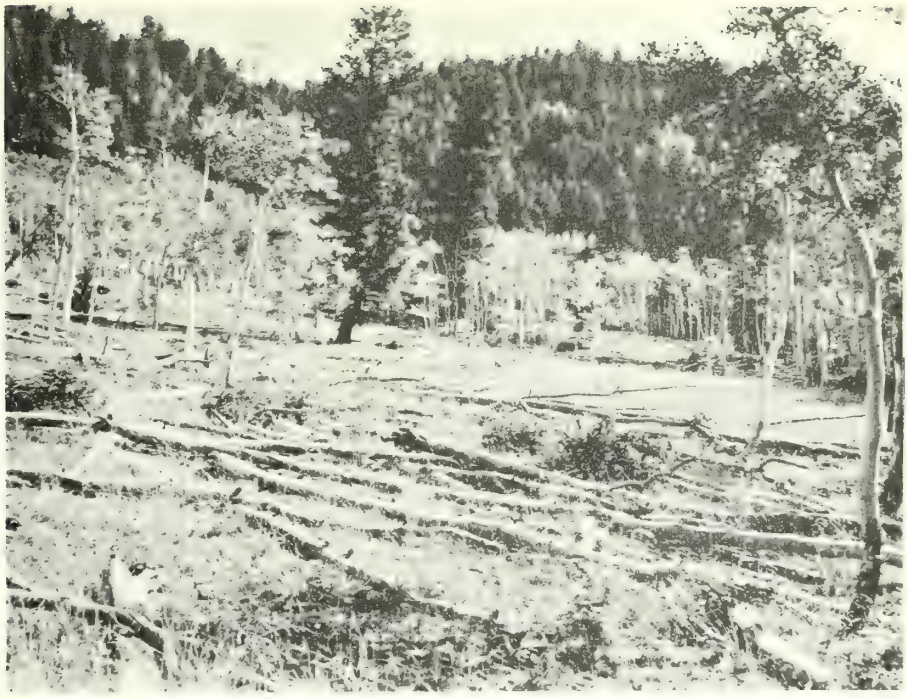

Fig. 1. Conversion of an aspen type to grassland by overgrazing. Sheep grazing on this poor condition aspen area is so heavy that vegetative aspen reproduction is unable to "get away." The older trees are dying, probably of disease, and since no trees are replacing them the stand is doomed to extinction unless grazing pressure is reduced.

Fig. 2. A virtually undisturbed aspen understory site. A dense ground cover, large percentage of palatable forbs, no undesirable plants, no accelerated erosion, and high production combine to indicate one of the most productive sites in the aspen type. This site is classified in good condition, verging on excellent.

Fig. 3. This grass understory in an aspen stand has been regarded as a model aspen type. Actually in only fair condition, it is a product of class overgrazing by sheep with the elimination of desirable forbs and aspen reproduction.

Fig. 4. A small, good-condition opening in the aspen type. This opening combines a high ground cover of palatable plants with a small percentage of undesirable plants, high production, and no erosion. Note Heracleum lanatum flower heads. Compare this picture with Fig. 2 and note small differences between good condition aspen understory and opening sites.

Fig. 5. An aspen understory site. This range is heavily used by cattle and will be gone over by sheep later in season. The ground cover of 57 percent vegetation and 26 percent litter, and high proportion of mountain brome place this site in fair condition.

Fig. 6. An aspen opening 25 yards east of site pictured in Fig. 5. This site likewise is in fair condition. It is described here under Area Y, opening.

Fig. 7. An aspen understory stand in very poor condition. The scanty vegetal ground cover, high proportion of annuals, low production, and lack of aspen reproduction combine to form one of the poorest aspen range sites in the aspen type.

Fig. 8. An aspen opening in very poor condition. This opening is dominated by niggerhead (Rudbeckia), dandelion, and annuals, with extremely low ground cover and production. The adjacent aspen understory, while consisting of much more vegetation than that shown in Fig. 7, is still in very poor condition. Aspen reproduction is entirely utilized each year.

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DELINEATING PONDEROSA PINE VOLUME AND SITE QUALITY CLASSES FROM AERIAL PHOTOGRAPHS

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U. S. DEPARTMENT OF AGRICULTURE

Ogden, Utah

DELINEATING PONDEROSA PINE VOLUME AND SITE QUALITY CLASSES FROM AERIAL PHOTOGRAPHS

Alvin K. Wilson, Forester

INTRODUCTION

During the past several years, many foresters have participated in forest inventory surveys in which aerial photographs were employed. More and more of them have come to appreciate the application of vertical aerial photography to a number of problems in forest management and to value the aids to their interpretation which have been developed. This appreciation stems from the fact that the judicious use of aerial photography can reduce the costs of timber surveys substantially or permit more intensive surveys than would otherwise be possible.

With some knowledge of ground conditions, stereoscopic examination of suitable photographs reveals a number of recognizable differences in timber stands such as cover type, cutover or virgin condition, and stocking and volume per acre class to name a few. It is from these differences that the advantages afforded by aerial photography are derived. Whether few or many classes or subclasses of timber stands are recognized and whether great precision in delineating them is possible or not, a stratification of the timber is achieved. Within a stratum (class of subclass) place-to-place differences will be smaller than place-to-place differences for the entire timberland area under study, making it possible to obtain a relatively reliable estimate for a given stratum from a comparatively small sample. Taking this effect into account for all strata, a more reliable estimate of the whole can be obtained from a considerably smaller total sample than would be necessary if the timberland were sampled without stratification. While relatively expensive field work is not eliminated by the employment of aerial photographs, its total amount for an estimate of predetermined reliability is reduced appreciably.

In the Intermountain region excellent use of aerial photography is being made by the Southwest Idaho Timber Survey and the national Forest Survey for a detailed summarization of timber resources on forest lands. When completed, the entire program for timber management in this area will be strongly influenced by the estimates obtained. Collection of information for other special problems in timberlands, such as forest protection planning and recreational area development, is being expedited by aerial photography. Rangers can find use for their files of prints in familiarizing themselves with their districts, in certain phases of forest protection, in outlining land ownership, and in studying timber distribution on sale areas.

More intensive use of aerial photographs by rangers to obtain information on district problems is desirable and could be promoted if interpretation aids capable of being employed by the nonspecialist were available. One type of aid which could be supplied to meet this requirement is the stereogram, a series of which picture a number of stand

conditions and permit interpretation of conditions in other stands by comparison. Interpretation by this means is not difficult and, with suitable stereograms, gives good results even though the rough topography of this region imposes some disadvantages in their application.

It should be pointed out that even the specialist would encounter difficulty in applying some interpretation techniques to photographs of the rugged topography of this region. While the comparatively wide spacing between trees, particularly in the ponderosa pine type, is an advantage in determining ground surface details, rapid changes in ground elevation cause wide variation in scale over short distances and complicate the process of obtaining tree and stand measurements by such aids as the parallax wedge and shadow scale. Consequently both the specialist and nonspecialist would be assisted in interpretation by stereograms.

The techniques employed in the installation of a moderately large-scale experiment in the conversion of virgin ponderosa pine to managed stands on the Boise Basin Experimental Forest[1/] may suggest adaptations or improvements for use by others engaged in forest management, administratively or experimentally. With this belief, methods and results are presented here with sufficient description of the experimental design to clarify the problem.

THE PROBLEM

This experiment is an adaptation of a design outlined by L. I. Barrett[2/] and required 16 compartments (minor drainages) in virgin timber in the ponderosa pine type, with each compartment containing a minimum of 10 acres in each of three classes of initial per-acre volume. The problem was therefore one of achieving a practicable means for stratifying certain areas of the experimental forest supporting virgin ponderosa pine into three volume classes and then delineating compartments of at least 30 acres, each of which met the volume-class requirements.

PROCEDURE

Compartment Selection

The photographs used in the office delineation of the three volume classes and subsequent selection of suitable compartments were 9-inch x 9-inch contact prints taken by the Soil Conservation Service in 1939 with a "representative fraction"[3/] of 1/20,000.

1/ Maintained by the Intermountain Forest and Range Experiment Station on the Boise National Forest near Idaho City, Idaho.

2/ Then (1950) Chief, Division of Forest Management Research, U. S. Forest Service.

3/ Average scale at a given elevation above sea level, in this case about 5,000 feet.

Nine locations were pin-pricked on these photographs within the virgin-timber portion of the experimental forest to sample a range of stand conditions at several elevations. These points were readily located on the ground by stereoscopic inspection of the photographs, and a sawtree tally made at each point on a one-half acre circular plot. In the office, the volume data and appearance of the plots under the stereoscope were used to make comparisons, while areas supporting volume classes of (1) less than 10 M board feet per acre, (2) 10 to 20 M b. f. per acre, and (3) over 20 M b. f. per acre were sketched on the photographs for the portion of the experimental forest in the ponderosa pine type.[4/] Topographic features were used in sketching in the compartment boundaries to make each minor drainage compartment a small natural logging unit. A transparent templet with a circle enclosing 10 acres at 1/20,000 R. F. was used to check volume class acreages in each compartment and aided in eliminating from further examination those compartments which did not meet requirements.

It will be appreciated that the above steps served mainly to narrow the field of potentially useful compartments to those which merited more intensive exploration. Being largely accomplished by office work, this procedure saved considerable time and effort that would otherwise have gone into field examination.

To obtain data for checking the reliability of the photo interpretation on the remaining compartments, about a 10-percent cruise of the 10 to 20 M b. f. per acre volume class was made using one-half-acre plots distributed with as little bias as possible. This was done by pin-pricking plot centers onto the aerial photos through a nontransparent overlay on which only compartment and volume-class boundaries appeared. The reasons for cruising only the medium volume class were: (1) A cruise of greater intensity could be made if efforts were concentrated in one volume class rather than spread over all three; (2) if the middle volume class proved to be delineated with sufficient accuracy, the heavier and lighter classes should also be correctly outlined.

The cruise data indicated that only a few adjustments in volume class lines were needed, which were readily made by using nearby plots as stereogrammic aids.

Compartment boundaries and volume-class lines were located on the ground by using a transparent overlay and stereoscopic examination of the photographs. Boundaries were marked with paint and traversed, followed by a 100-percent cruise of each volume-class area. The purpose of this cruise was to provide a high degree of control over the volume removals to be made in attaining the desired volume reserves.

4/ During the course of the study as many as 5 volume classes were delineated, but due to insufficient representation of each on the study area it was decided to use the 3 classes described here.

Height-Diameter Data

Because the physical arrangement of the three volume classes agreed with the expectation that the heaviest timber stands would occur in gulch bottoms and lower slopes, medium volumes of timber on middle slopes, and the lightest volumes on upper slopes and ridges, it was also expected that site quality differences would be found between them and that such differences should be reflected in the local volume tables.

Sample trees were measured for total height and diameter in each of the three volume classes of eight compartments. Since the main drainage of the experimental forest is to the north, the compartments selected for this sampling represented both east and west aspects. Sample trees were obtained along a north-south line through the middle of each volume-class area with as little bias as possible consistent with obtaining a full and fairly even distribution of diameters.

Height-diameter data were plotted and curved independently for each of the three volume classes. When compared, it was found that no curve intersected or touched another and that they were arranged in the order of the volume classes they represented (fig. 1).

RESULTS

Volume Classes

Volumes per acre are given in table 1 for the volume-class areas which were cruised 100 percent. Of the 48 areas cruised, five fell below the lower limit of the class into which they were expected to fall but only two of these missed by an appreciable amount. In one of these instances heavy Douglas-fir mortality which occurred after the photographs were taken contributed to the overestimate.

The use of aerial photographs served to (1) eliminate a large amount of field work which otherwise would have been required in inspecting unusable compartments, (2) stratify the timber in each of 16 compartments into three volume classes, and (3) furnish a means for locating and delimiting volume-class areas on the ground.

Volume-Site Class Relationship

The harmonized height-diameter curves of figure 1 indicate that differences in site quality exist between the three volume classes. However, the two lower curves do not differ as markedly as the upper curve differs from the middle one. Referring to site quality curves,[5/] the average heights of mature trees show that the lowest volume class is medium site IV, the 10 to 20 M b. f. per acre class is good site IV, while the highest volume class occurs on medium site quality III.

5/ Meyer, Walter H. Growth in selectively cut ponderosa pine forests of the Pacific Northwest. U.S.D.A. Tech. Bul. 407, 64 pp. 1934.

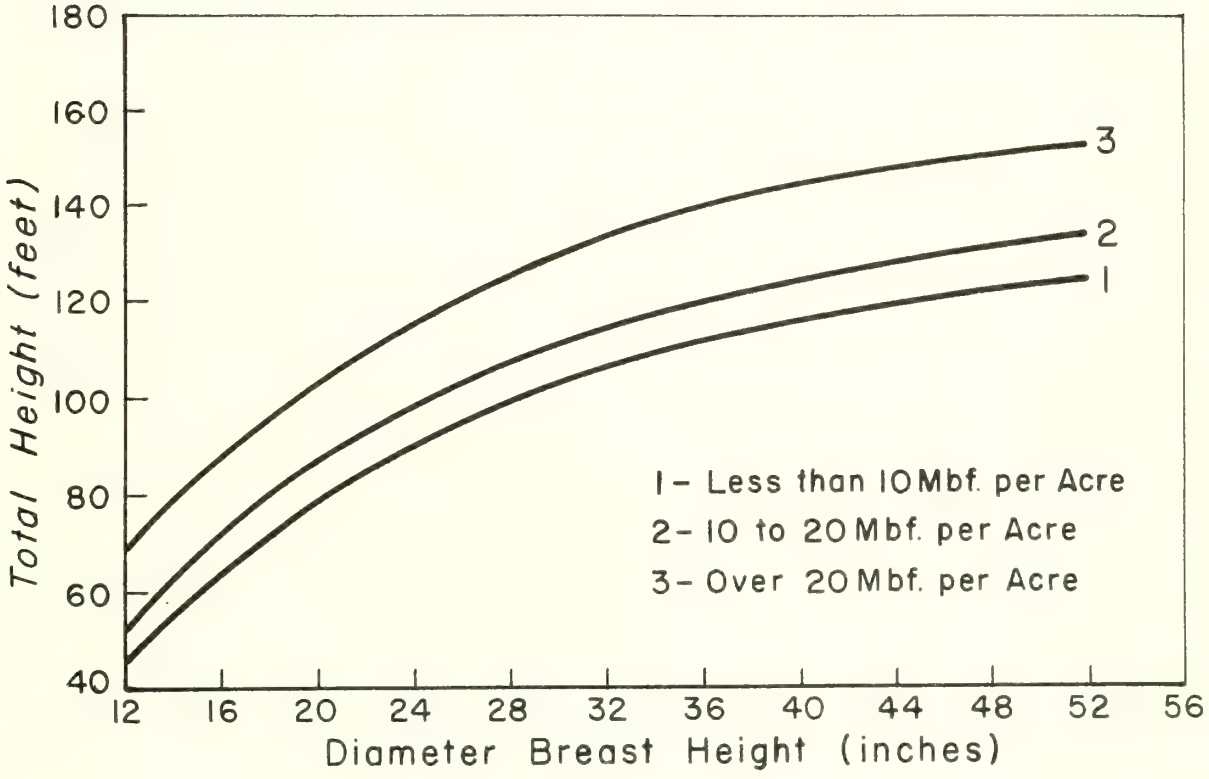


Figure 1.--Harmonized total height-diameter curves for three volume-per-acre density classes.

Table 1.--Volume per acre (Scribner) for volume-class areas[1/] cruised 100 percent

Compartment	Volume class		
	Less than 10 M b. f. per acre	10-20 M b. f. per acre	Over 20 M b. f. per acre
	Board feet	Board feet	Board feet
1	7,500	17,800	23,700
4A	5,600	14,700	19,600
4B	6,300	9,800	30,200
5	4,700	11,700	26,400
7	3,700	17,900	34,700
8A	7,600	17,800	27,300
8B	5,100	16,900	25,500
9	6,100	18,400	26,100
11A	4,500	19,400	25,700
11B	5,100	16,900	27,100
15-16	8,800	16,000	17,700
17	8,700	16,100	21,000
20	5,300	13,200	19,200
24A	5,400	13,500	21,000
24B	5,000	16,300	16,700
28	7,000	16,300	21,900

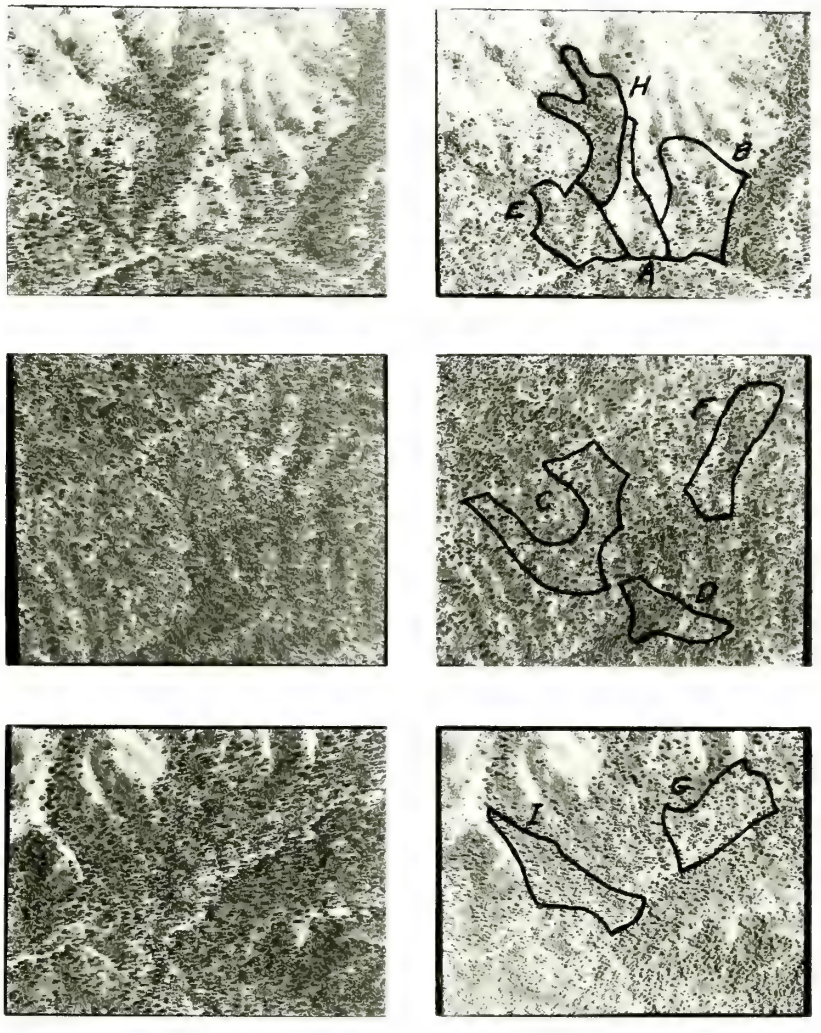
1/ Total area involved in the study is 847 acres, with compartments ranging from 32 to 79 acres. Volume-class areas within compartments range from 8 to 33 acres.

Although the purpose of the delineation procedure was to separate volume classes, the tree height data show that a separation into two site quality classes was made at the same time.

Volume-Class Stereograms

Completion of the inventory cruise on many of the volume-class areas within the 16 compartments affords a series of examples of the appearance of ponderosa pine stands for several volume-per-acre categories. These are shown in the form of stereograms in figure 2 with pertinent data in companion table 2.

For the illustration of some of the structural variability of stands avereging up to 20 M b. f. per acre, paired examples are included; higher average volumes are illustrated by single examples. Stereograms for the very lightest volumes (below 9.2 M b. f. per acre) are not included since such areas are easily recognized by comparison and most often include areas of the protection type along ridges.



Stereo-pair	Average volume per acre (M.B.F. Scribner)	No. of sawtrees per acre	Percent Douglas-fir (by volume)	Acreage outlined
A	9.2	16.8	2.9	7.6
B	11.7	15.2	1.4	19.3
C	15.5	19.1	3.2	24.1
D	16.0	24.5	22.2	6.4
E	19.6	27.6	5.9	11.5
F	21.0	32.3	20.3	14.7
G	25.5	27.8	7.0	13.0
H	30.2	22.6	11.9	12.2
I	34.7	31.6	3.7	14.8

Figure 2 and Table 2. Stereopairs and interpretation data for nine volume-per acre classes in virgin ponderosa pine. North is to left.

SUGGESTIONS FOR USE OF STEREOGRAMS

As indicated by the height data within volume classes, the stereograms illustrating volumes below 20 M b. f. per acre could be used in delineating areas of site quality IV in virgin ponderosa pine and those for areas above 20 M b. f. per acre as guides to areas of site quality III. This use would produce a division of timbered areas into two strata in each of which sampling intensity could be adapted to accuracy requirements. However, the delineation of site quality classes on this basis would be applicable only in central Idaho. Still more advantageous use of stereograms such as these could be made by using them as guides in delineating a number of volume-class areas. This procedure would produce more and narrower strata and afford the opportunity for increasing sampling efficiency while reducing the over-all sampling intensity required.

For example, the ranger in charge of a sale area could delineate as many volume classes as practical directly on the aerial photographs of the area, using the stereoscope and stereograms and taking advantage of his familiarity with general ground conditions. In each class distinguished, a number of ground sample plots could be selected in either of two ways: (1) by pin-pricking randomly located points on the photographs using a nontransparent overlay and locating them on the ground by inspection of the photographs, or (2) by using, on the ground, some system that would remove personal bias in locating plots and using the photographs to pin-point the photo location of each plot. With a little experience, pin-pricked plot centers can be located with assurance on the ground by inspection of the photographs under the stereoscope. The main considerations in either of the methods suggested above for locating plots are orienting the photographs, being able to estimate distances on them, and keeping track of one's position on the ground and on the photograph.

Data on the area occupied by each volume class would best be obtained with the aid of a reflecting projector in the office where a map of the area could be made from the photographs or the lines on the photographs transferred to an existing map. At this time an analysis of the plot data could be made to determine the need for further ground sampling, keeping in mind that a point in sampling intensity will be reached beyond which added sampling will be uneconomical in comparison with the increase in accuracy of estimate.

Heath[6/] cites instances from his experience with timber sales in the Southwest where he used techniques, evidently similar to those suggested here, and obtained estimates of cut that agreed remarkably well with the actual cut.

6/ Heath, G. R. 1953. Simple devices aid use of aerial photographs. Jour. Forestry 51: 125-127.

Among the results of the Southwest Idaho Timber Survey will be planimetric maps showing cover types and their status in considerable detail. Within a type the classification of sawtimber stands, in order to conform with national Forest Survey standards, is very broad, including volumes per acre of 1,500 bd. ft. and above. This is further subdivided into areas of good, medium, and poor stocking with estimates of average volume per acre and species composition for each. These delineations will furnish a stratification of timberlands which can be employed advantageously in sampling and should contribute significantly to more economical cruising procedures. An additional refinement which would lend itself to still further economies in sampling would be the use of stereograms to delineate areas of different volume classes within these broader strata.

In making comparisons with these stereograms, differences in the density of tree crown cover from one stereogram to another should be noted as well as general tree heights and crown widths. Where low densities of tree cover occur at higher elevations, as in the protection type and its intergradation to merchantable stands, apparent tree sizes may be exaggerated due to nearness to the camera and the wider crowns that accompany wider spacing of stems. Unless this effect is considered, the tendency will be to overestimate average volumes. As the percentage of Douglas-fir increases, the effect is to lower average volumes. This is demonstrated to some extent in the data accompanying the stereograms and should be taken into account where this percentage reaches 20 and over.

As experience is gained in relating ground plot data to the appearance of the same plot on the aerial photographs, a local file of photo plots with accompanying ground cruise data can be built up which can be employed in a sampling design similar to that of the national Forest Survey. In the Survey a large number of photo plots are interpreted while only a small proportion of them are checked on the ground to provide adjustment factors for the photo plot data.

SUMMARY

Vertical aerial photographs afford the means for making economical and accurate surveys of timberlands when suitable aids are available for use with them. Consequently the development and application of such aids should be encouraged.

To suggest ways in which aerial photographs may be used to obtain data on localized areas, the procedure followed in installing an experiment in the conversion of virgin ponderosa pine to managed stands which saved considerable time and effort in field exploration, is described. The volume-per-acre classes delineated in the course of this work were found to bear a relationship to site quality classes III and IV for the area studied.

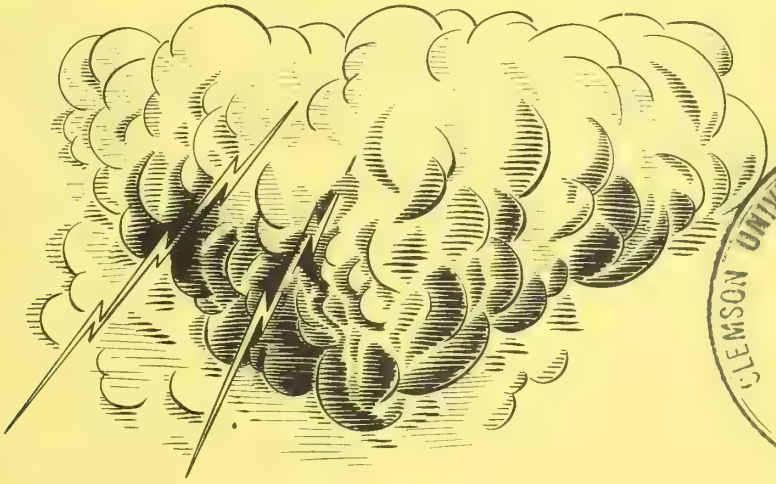
A by-product of the installation work is presented in the form of nine stereograms showing the appearance of ponderosa pine stands ranging in average volume from 9.2 to 34.7 M b. f. per acre. These stereograms are based on 100-percent cruises of the areas outlined and afford, because of their size, some advantages for use in very rough topography not provided by the usual plot-size stereograms. Suggestions for the use of these and similar stereograms for improvement in the accuracy and economy of timberland sampling are presented.

PROJECT *Skyfire*

A PROGRESS REPORT ON LIGHTNING FIRE AND ATMOSPHERIC RESEARCH

by

J. S. Barrows Vincent J. Schaefer and Paul B. MacCready Jr.



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PROJECT SKYFIRE

--A Progress Report On Lightning Fire and Atmospheric Research.

by

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Paul B. MacCready, Research Associate, The Munitalp Foundation, Inc.

November 1954

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SUMMARY

This report describes the factors which led to the establishment of Project Skyfire and presents the first results of its operation. Skyfire is a program designed to acquire basic scientific information about lightning fires in western forests, the atmospheric and cloud conditions which produce them, the nature of the local weather before, during, and after their occurrence, and the possibility of modifying lightning storms by cloud seeding.

The Skyfire cloud survey is based on an integrated network of mountain-summit stations. During the summer of 1953 twenty-five of these stations were manned by forest-fire observers who were given special training in cloud identification during a 3-day period of intensive instruction just prior to reaching their lookout stations.

The area covered by these special observations consists of about 20 million acres of forested mountains in eastern Washington, northern Idaho, western Montana, and northwestern Wyoming. In this region more than 70 percent of the forest fires are caused by lightning.

In making the daily cloud surveys a simple coding system was used to report the geographic location of small cumulus clouds and their subsequent life cycle. Data were also obtained on middle and high clouds in order to study the relationship of certain distinctive cloud forms and characteristics to fire weather and the presence or absence of a jet stream in the vicinity.

At key mountain locations special time-lapse movie cameras were installed to obtain typical cloud records. A special sphere camera photographed the day-by-day life cycle of clouds in suspected cloud-breeding areas.

The results of the first season's operation were very satisfactory. Preliminary results imply a good correlation between certain fast-moving altocumulus and cirrus clouds and the presence of the major axis of a jet stream. Some of the most serious of the lightning fire outbreaks showed a close relationship to the presence of a jet stream over the area. More than 2000 feet of time-lapse cloud movies were obtained. Some of these indicate the importance of the southwestern area of the region as a primary source of the fast-moving type of thunderstorm which sweeps over the observation area.

Based on the findings of the 1953 season a group of 17 stations in the northern Rockies and Oregon operated in 1954. In the middle of the 1954 fire season 8 cloud survey stations were added in California. Special attention was given to suspected cloud-breeding areas. Improved methods of reporting cloud observations have been devised and a new cloud manual made available. Special reports were transmitted over a radio network to permit the plotting of daily cloud maps. Special weather analyses were prepared on a daily schedule. The Munitalp-University of Washington-Forest Service mobile weather observatory was employed in the field for special observations.

Figure 1. Typical lightning-caused fires in northern Rocky Mountain forests.

I. THE LIGHTNING FIRE PROBLEM

Project Skyfire is basic research of the atmosphere and its relation to lightning fires in western forests. The long-range objectives of Project Skyfire are to gain a better understanding of the atmospheric factors influencing the occurrence, behavior, and control of lightning fires and to determine the feasibility of preventing or reducing lightning fires through cloud-modification operations.

LIGHTNING FIRE CHARACTERISTICS

Lightning fires are a multimillion-dollar problem in western forests (figures 2 and 3). During the 23-year period 1931-1953 over 134,000 lightning-caused forest fires occurred in the western United States. Nearly 2,000,000 acres were burned by these fires. In the Rocky Mountain States 65 percent of the forest fires are lightning caused (1).

The number of lightning fires varies widely from year to year (figure 4). The great variations in lightning-fire occurrence are due both to the individual characteristics of lightning storms and to the dryness of fuels in the storm areas. Some lightning storms are accompanied by a considerable amount of rain which reduces the number of fires started, but a more common pattern in western forests and especially in the Rockies is for very little rain to occur with the summer storms. Sometimes relatively mild storms can produce disastrous fire situations if pre- and post-storm weather is dry and windy. In the national forests of western Montana and northern Idaho over 300 lightning fires have started in a 24-hour period (2). In the same area daily loads of 50 or more lightning fires occur in every month from May through September and in July, 1940, nearly 1500 fires occurred in a 10-day period (figure 5).

Zones of lightning-fire occurrence have been determined from studies of thousands of fires (1). These studies have shown the ignition rate of lightning fires by time of day and elevation zone in the northern Rockies (figures 6 and 7). As a result of this research the general trouble spots are known and it is now possible to proceed with the next step of finding and recording the action of the cloud-breeding spots for these areas.

One of the major factors in lightning fires is their behavior in the initial stages following ignition (3). The meteorological factors associated with lightning may either favor, or retard the initial rate of spread of fires. Moisture accompanying some storms retards ignition and initial rate of spread. In some cases moisture makes the fire-detection job difficult because of the tendency for the fires to smolder and show little smoke. Later when dry weather comes, these fires may appear unexpectedly several days after the lightning storm which started them. Severe downdraft winds are frequently associated with lightning storms. These winds may fan freshly started fires, blow sparks from strikes in snags and treetops, and scatter burning embers to surrounding fuels.

Figure 2. In critically dry weather, lightning fires like this one may spread rapidly over large forest areas.

Figure 3. Lightning fires often start near ridgetops in rough, mountainous country where control operations are difficult and expensive.

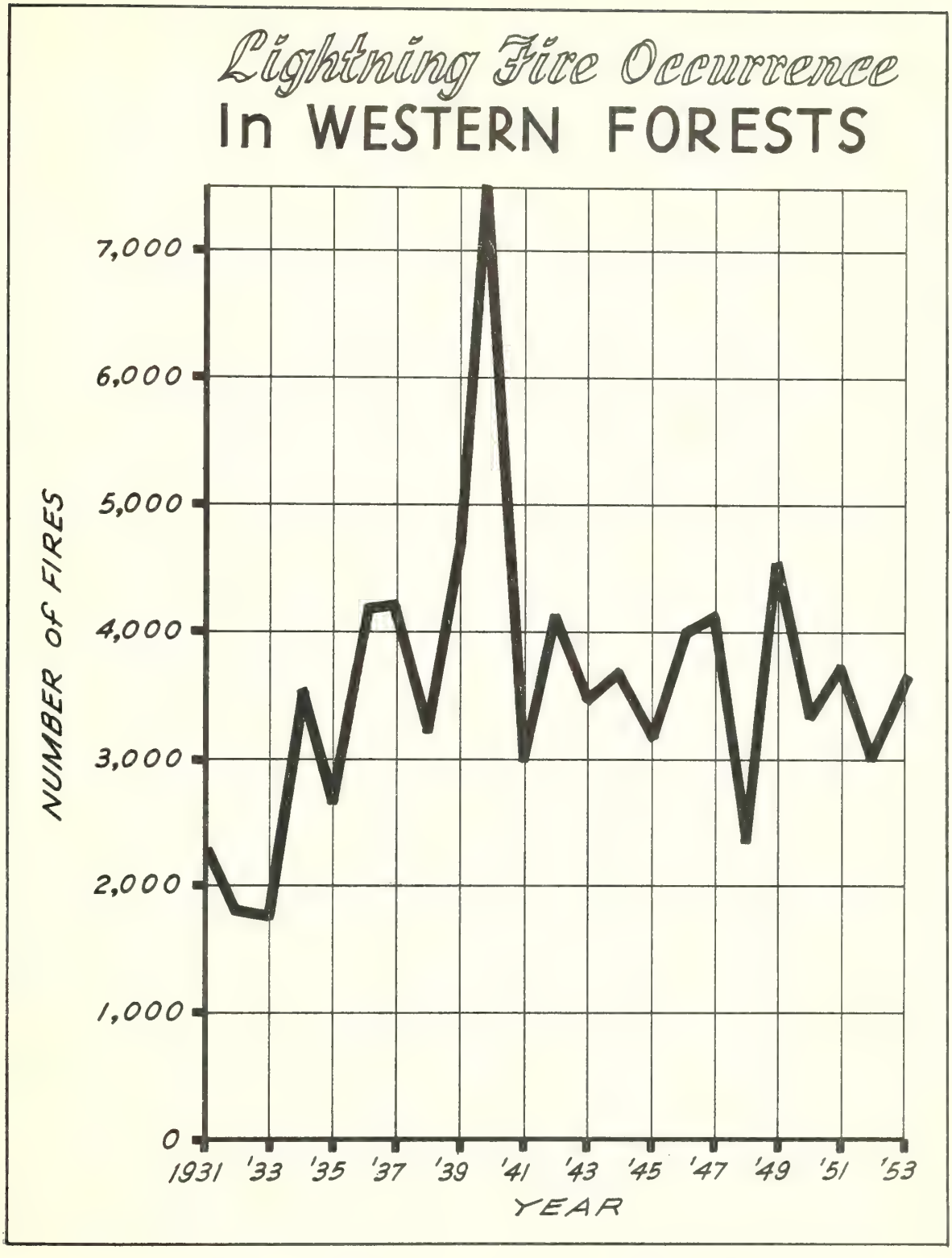


Figure 4. Lightning fire occurrence on lands protected by Federal, state, and private agencies in the 12 western states, 1931-1953. (Basis 134,534 fires reported to U. S. Forest Service in states of Montana, Idaho, Wyoming, South Dakota, Colorado, New Mexico, Arizona, Utah, Nevada, Oregon, Washington, and California.)

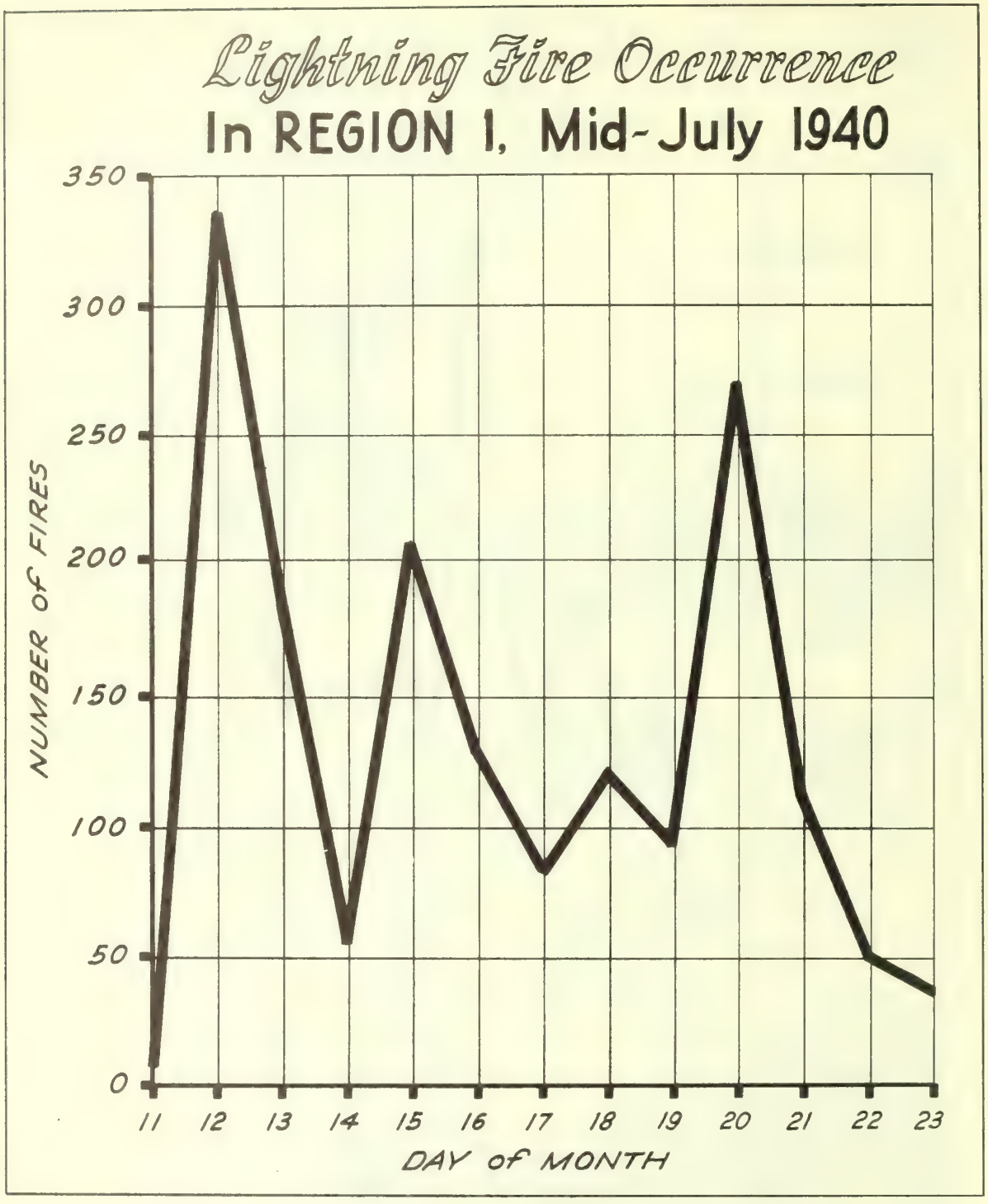


Figure 5. Lightning fire occurrence in national forests, Region 1, mid-July 1940.

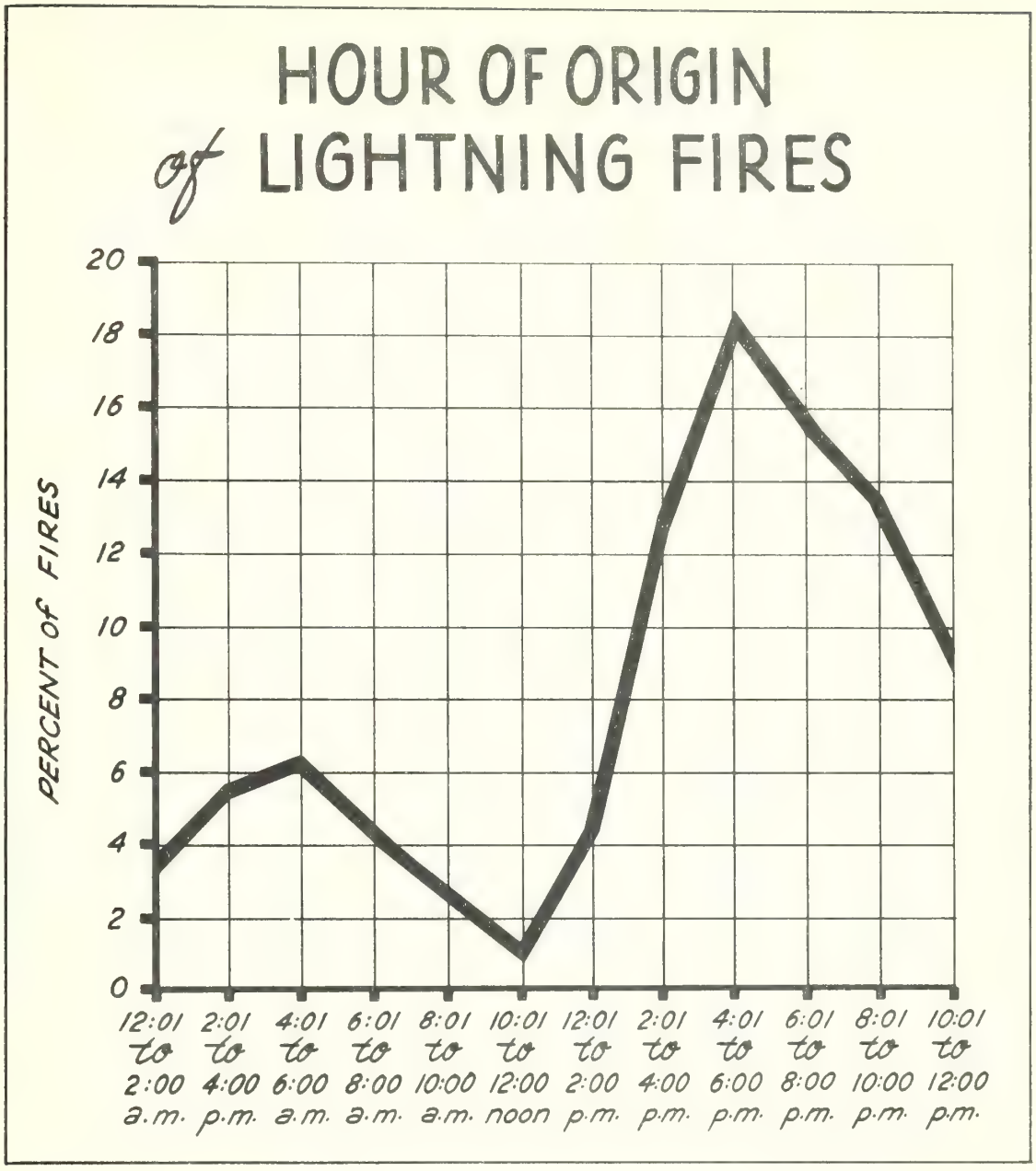


Figure 6. Percent of lightning fires starting in each 2-hour period, national forests west of Continental Divide, Region 1.

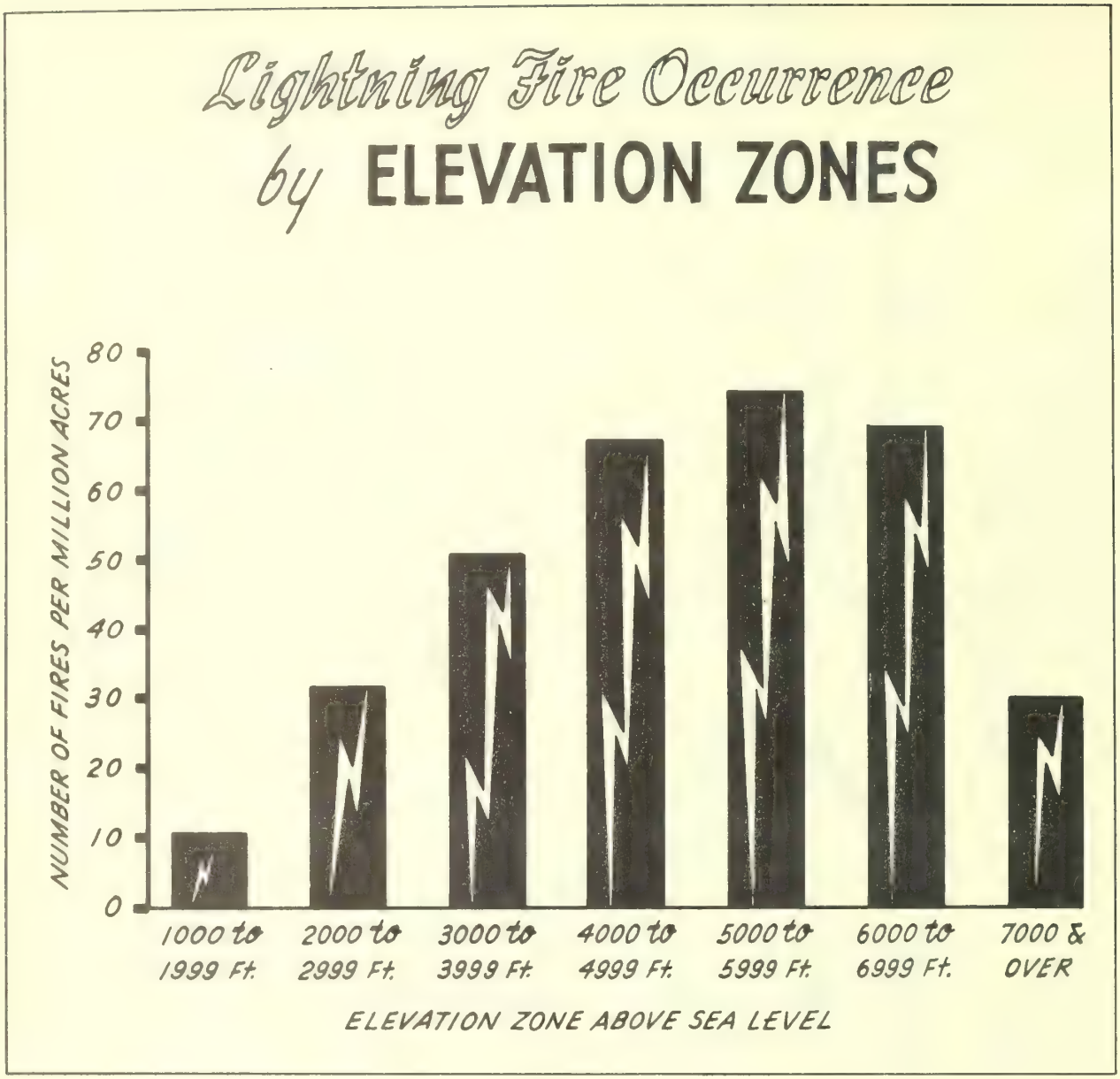


Figure 7. Average annual number of lightning fires per million acres by elevation zone above sea level, national forests west of Continental Divide, Region 1.

THE LIFE CYCLE OF LIGHTNING FIRES

The concern of forest-fire-control organizations in lightning fires begins with the prediction that a storm may occur and continues through the various stages of cloud development, lightning action, precipitation, storm dissipation, and post-storm weather. Documentation of the complete life cycle of lightning fires including pre- and post-storm weather and the details of the storm itself is of great importance in the development of a better understanding of fire-control requirements. The development of such life-cycle information is one of the prime objectives of Project Skyfire.

The meteorological factors associated with lightning are complex and not fully understood. Continued research is necessary to probe the remaining unknowns of lightning phenomena. Project Skyfire hopes to provide some of this information and especially that related to cloud formation over the western mountains. Questions to receive attention include: When and where do cumulus clouds form? What are the most important cloud-breeding areas? What are the major lightning-storm paths? What are the relationships of middle and high clouds to the jet stream, and the jet stream to lightning-fire occurrence and behavior?

THE RESEARCH OPPORTUNITY

Progress in meteorology and forestry point to the opportunities for developing better methods for the control--and possibly for the prevention--of lightning fires. More knowledge is being gained of the atmosphere--of clouds and their action, of high-altitude winds, of regional climatic patterns, and of the dynamics of weather. Experience in forest-fire-control operations has indicated the general characteristics of lightning fires. Recent forest-fire research has provided general information on when and where lightning fires occur and on their severity according to fuel, topography, and surface weather conditions (1).

The experiments of Project Cirrus (10, 12), and of numerous industrial and commercial meteorologists have demonstrated that convective clouds may be altered through cloud-seeding operations. Research workers in many countries of the world are performing theoretical and experimental research on cloud physics. In the United States there are now many research and commercial cloud-modification programs underway. Research has been started on hail prevention through cloud-modification processes; this may be closely related to lightning reduction. Some efforts are being made to prevent lightning storms by both ground and aerial seeding operations.

Forest-fire-control organizations in the western United States are uniquely equipped to assist in atmospheric research. Personnel at mountain-top forest-fire lookout stations are in a commanding position to make regular observations of clouds and lightning storms. Likewise the pilots, fire observers, and smokejumpers of the aerial fire-control

foresters can assist in obtaining information needed in atmospheric and lightning fire research. Throughout the western United States a network of fire-weather stations provides data related to lightning fire occurrence and behavior. The radio communications systems of fire-control organizations enable rapid transmission of lightning, cloud, and general fire-weather reports for daily analysis by research personnel.

The over-all impact of these developments in meteorology and forestry is the creation of a favorable situation for atmospheric and lightning fire research. The need for such research is great and the opportunities for progress are equally great.

THE EARLY RESEARCH EFFORTS

In 1947 Mr. Harry Gisborne, then Chief of Fire Research at the Northern Rocky Mountain Forest and Range Experiment Station of the U. S. Forest Service, visited Dr. Vincent J. Schaefer, then a Research Associate at the General Electric Research Laboratory, Schenectady, New York, for a discussion of thunderstorms and the possibilities of preventing their formation. Schaefer told Gisborne that, based upon current knowledge and the new discoveries likely to follow the intensive research effort then getting underway, there was a good chance that one could hope eventually to exercise some degree of control over damaging storms. He pointed out the need for acquiring field data by direct observation and was invited to initiate such a program in the northern Rocky Mountains.

In July and early August of 1948 Schaefer, Gisborne, and Barrows observed, photographed, and measured a number of thunderstorms which occurred in the Selkirk Mountains of northern Idaho. In a report prepared at the end of the season a number of recommendations were made (15). These pointed up the distinct possibility that the local storms might be modified by proper seeding methods but emphasized the importance of gathering much more field data by mountain-top observations.

Some of these recommendations were carried out during 1949 but the observational and research program suffered a great loss with the untimely death of Harry Gisborne.

THE MUNITALP-FOREST SERVICE PROGRAM

In 1952 the Munitalp Foundation, Inc., under the technical direction of Schaefer, inaugurated a program of time-lapse photography of clouds with the objective of acquiring a series of movies which would show typical cloud formations in various parts of the world. As part of this program the cooperation of the U. S. Forest Service was sought since it was felt that mountain-summit fire-lookout stations would be excellent sites for obtaining such pictures. Several sites were selected in the national forests and parks of the Rocky Mountains. These were supplied with time-lapse movie units operated by local, relatively untrained personnel. An excellent series of cloud movies were obtained during that summer. The demonstration that good results could be achieved in this manner revived interest in the lightning-storm field study. As a result of discussions between Barrows and Jemison of the Forest Service and Schaefer of the Munitalp Foundation it was decided to establish a cloud survey in the national forests of western Montana, northern Idaho and eastern Washington.

The approach to the lightning-storm study of Project Skyfire emphasizes fundamental investigations of cloud types and structures and the related properties of the atmosphere such as moisture, nuclei, radiation, wind, and atmospheric electricity. Many of these data can readily be gathered at fire-lookout stations.

The facilities established for lightning research also provide opportunities for investigation of other meteorological problems associated with forest fires. Project Skyfire is concerned with questions such as the forecasting of strong winds; the relation of high clouds and jet streams to surface conditions; and the study of local winds and convection. An important facet of the field program is the development of new cloud-survey techniques based on the utilization of networks of key mountain-summit lookouts.

CLOUD MODIFICATION

Can lightning fires be prevented or reduced through cloud seeding? The final objective of Project Skyfire is to evolve some sort of practical weather-control method decreasing the incidence of lightning fires. In working toward this end it will be necessary to gain considerable quantitative knowledge of particular cloud-breeding spots in this area, of cloud heights and trajectories, of condensation and freezing nuclei counts, and of other factors which affect the growth of thunderstorms. In addition, analyses will be undertaken to show just how these factors are related to lightning. For such purposes the cloud survey will be continued and strengthened, and the mobile meteorological laboratory will be regularly employed. As with any rather fundamental research program the final objective is not the only goal; the measurements and analyses will also help give a better understanding of fire-weather and fire-behavior problems, and provide background for the investigation of characteristics of the jet stream.

Figure 8. Forest-fire lookouts are in a commanding position to observe and measure clouds.

II. THE CLOUD SURVEY

During the forest-fire seasons of 1953 and 1954 the Project Skyfire cloud survey was conducted from a network of fire-lookout stations (figure 8). In 1953 the survey was made from 25 stations in the northern Rockies. In 1954 the northern Rocky Mountain network was reduced to 17 stations (figure 9). Eight fire-lookout stations in California commenced cloud-survey operations during the latter part of the 1954 fire season.

CLOUD SURVEY OBJECTIVES

Clouds are dynamic indicators of weather. They are, of course, especially related to lightning. Clouds can be of assistance in studying wind movement, convection, and the moisture content of the atmosphere. Observation can show fairly well whether the cloud is composed of ice crystals or water droplets and whether the atmosphere is stable or unstable. Keen observation of clouds may assist in evaluating fire behavior (3).

The specific objectives of the Project Skyfire cloud survey are:

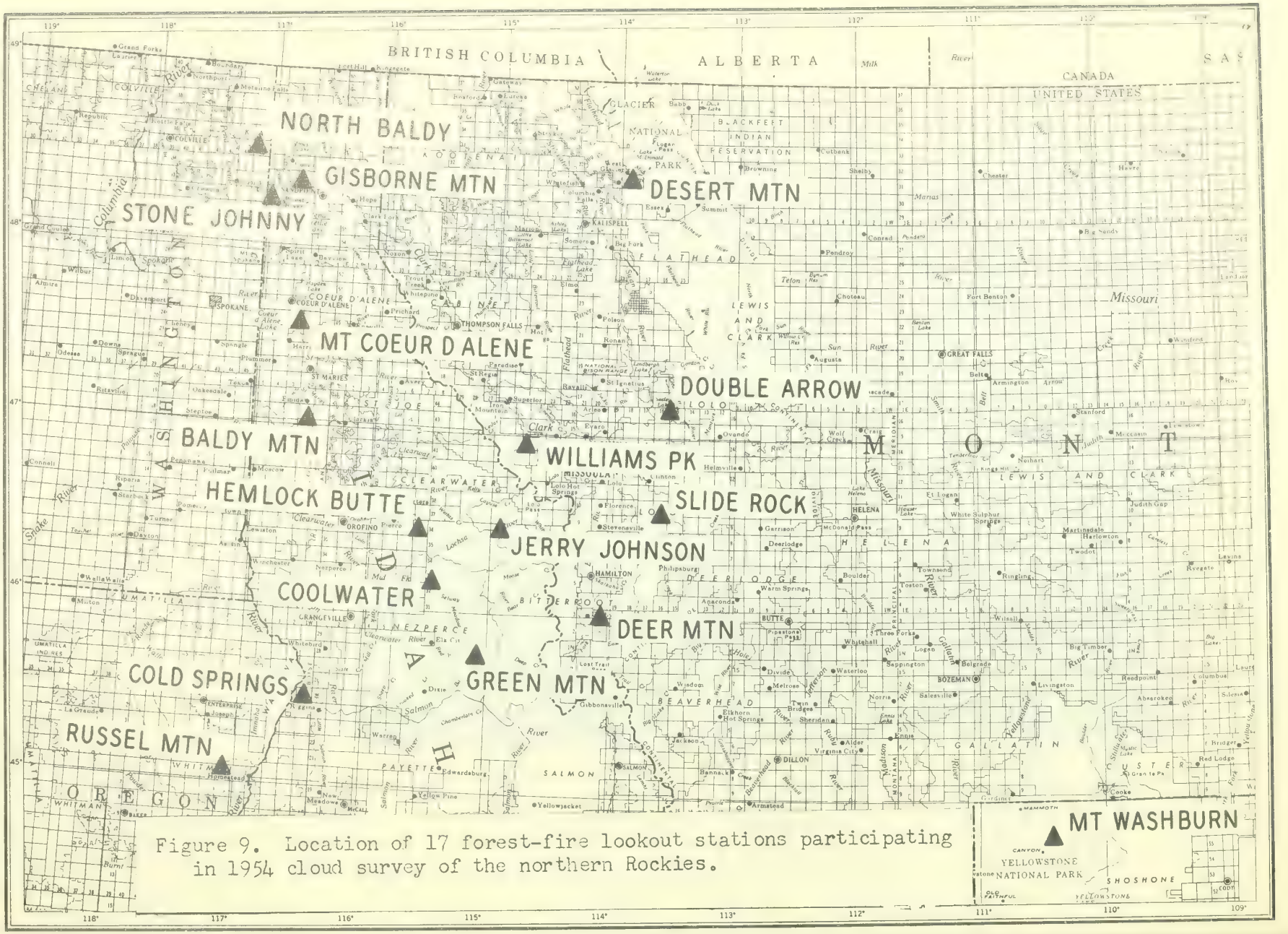
1. To observe, report, and map the development, movement and action of cumulus clouds, and high- and middle-level clouds.

2. To detect any cloud-breeding sites from which lightning storms may frequently develop.

3. To observe, report, and map lightning occurrence and intensity.

4. To obtain time-lapse motion pictures of clouds in selected areas.

5. To observe cloud action in relation to other atmospheric factors and especially to the weather factors influencing forest-fire danger.


NORTH BALDY
GISBORNE MTN
DESERT MTN
STONE JOHNNY
MT COEUR D'ALENE
DOUBLE ARROW
BALDY MTN
WILLIAMS PK
HEMLOCK BUTTE
SLIDE ROCK
JERRY JOHNSON
COOLWATER
DEER MTN
COLD SPRINGS
GREEN MTN
RUSSEL MTN
MT WASHBURN
BRITISH COLUMBIA
ALBERTA
CANADA
UNITED STATES
GLACIER NATIONAL PARK
BLACKFEET INDIAN RESERVATION
FLATHEAD
LEWIS AND CLARK
YELLOWSTONE NATIONAL PARK
SHOSHONE
WASHINGTON
IDAHO
MONTANA
OREGON
COLVILLE
KOOTENAI
CABINET
ST JOE
CLEARWATER
NEZPERCE
BITTERROOT
DEERLODGE
HELENA
BEAVERHEAD
GALLATIN
MADISON
SALMON
PAYETTE
WHITMAN
UMATILLA
Columbia River
Snake River
Missouri
Clark Fork
Flathead Lake
KALISPELL
COEUR D'ALENE
SPOKANE
THOMPSON FALLS
GREAT FALLS
MISSOULA
HELENA
BUTTE
BOZEMAN
DILLON
ORANGEVILLE
LEWISTON
ORofino
HAMILTON
SALMON
ENTERPRISE
Joseph
Hyprostead
Edwardsburg
Yellow Pine
Yellowjacket
Armstead
Gibbonville
Dixie
Whitebird
Elk City
Lost Trail Pass
Lolo Hot Springs
Florence
Stevensville
Deerlodge
Philipsburg
Anaconda
Warm Springs
Boulder
Townsend
Three Forks
Whitehall
Logan
Belgrade
Livingston
Reedpoint
Columbus
Absaroka
Big Timber
Silesia
Laurel
Red Lodge
Cooke
Divide
Waterloo
Melrose
Norris
Salesville
Twin Bridges
Sheridan
Ennis
Virginia City
Alder
Jackson
Bannack
Elkhorn Hot Springs
Wisdom
Pipestone Pass
Big Hole River
Madison River
Gallatin River
Yellowstone River
Missouri River
Marias
Sun River
Smith River
Judith
Musselshell
Milk River
Kootenai River
Pend Oreille
Priest River
Coeur d'Alene Lake
Spirit Lake
Newport
Boundary
Metaline Falls
Northport
Grand Forks
Republic
Kettle Falls
Colville
Chewelah
Deer Park
Davenport
Cheney
Medical Lake
Sprague
Ritzville
Odessa
Wilbur
Almira
Coulee City
Grand Coulee
Soap Lake
Ephrata
Wenatchee
Moses Lake
Othello
Connell
Pasco
Kennewick
Prosser
Sunnyside
Toppenish
Yakima
Ellensburg
Cle Elum
Roslyn
Kittitas
Thorp
Cashmere
Leavenworth
Chelan
Entiat
Waterville
Coulee Dam
Grand Coulee Dam
Omak
Okanogan
Tonasket
Oroville
Brewster
Pateros
Twisp
Winthrop
Mazama
Methow
Conconully
Loomis
Nespelem
Inchelium
Kettle River
Republic
Curlew
Tonasket
Oroville
Molson
Chesaw
Bodie
Wauconda
Tiger
Usk
Cusick
Newport
Priest River
Sandpoint
Bonners Ferry
Porthill
Naples
Moyie Springs
Bonner's Ferry
Libby
Troy
Eureka
Rexford
Whitefish
Columbia Falls
Hungry Horse
Martin City
Essex
Summit
Marion
Somers
Big Fork
Bigfork
Polson
Ronan
Pablo
St Ignatius
Arlee
Dayton
Lamar
Evaro
Frenchtown
Missoula
Lolo
Hamilton
Stevensville
Florence
Lolo Hot Springs
Clinton
Bonner
Milltown
Deer Lodge
Anaconda
Butte
Pipestone Pass
Whitehall
Three Forks
Logan
Belgrade
Bozeman
Livingston
Reedpoint
Columbus
Absaroka
Big Timber
Silesia
Laurel
Red Lodge
Cooke
Divide
Waterloo
Melrose
Norris
Salesville
Twin Bridges
Sheridan
Ennis
Virginia City
Alder
Jackson
Bannack
Elkhorn Hot Springs
Wisdom
Gibbonville
Dixie
Whitebird
Elk City
Lost Trail Pass
Florence
Stevensville
Deerlodge
Philipsburg
Anaconda
Warm Springs
Boulder
Townsend
Three Forks
Whitehall
Logan
Belgrade

CLOUD SURVEY METHODS

Mountain tops are ideal locations for making cloud observations. As a general rule the area under observation covers a radius of 20 miles from the mountain summit although clouds may often be seen and identified at distances in excess of 100 miles. Thus each station observes an area somewhat in excess of 750,000 acres. The regions of observation from certain of the stations overlap slightly, for effective coverage.

During the summer of 1953, the Skyfire lookout observers were asked to fill in data every hour (oftener if needed) on a report form to record cumulus development, upper-cloud condition, and lightning activity. At specially designated times, the lookouts radioed or telephoned a "flash report" to give a picture of the cloud situation. At certain of the stations time-lapse movies were taken as the meteorological situation warranted.

For cumulus cloud types (figure 10), the information required every hour and at every major weather change was: type of cloud(s), direction and distance from the lookout, direction of cloud motion, and any pertinent notes. For upper-cloud conditions, information was recorded indicating the presence of cirrus, cirrocumulus, altocumulus lenticular, or altocumulus billow clouds, a rough plot of where the upper clouds existed around the station, a check if the clouds extended horizon to horizon, the direction of cloud motion and their speed (fast or slow), and the surface wind direction and speed. For lightning activity, the number of strikes, time, and direction were requested. During a typical day, three or more pages of data would be accumulated from each lookout observer.

Measurement apparatus at the lookouts consisted mainly of a firefinder, a circular map table on which was mounted a rotating azimuth indicator (figure 11). Some of the firefinders also had provision for measurement of elevation. The eaves of the lookout station, however, prevented the use of the firefinder on any clouds except those at low angular elevations.

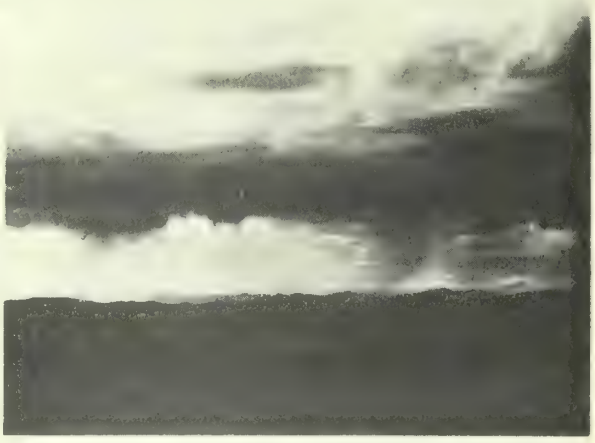
Of the data gathered, the most precise appear to be the locations of the first cumulus clouds. The lookouts encountered various problems in filling out the forms, and the training and followup were not adequate to rectify all troubles completely. Therefore interpretation of a considerable portion of the data was difficult. In order to obtain better data and ease the work of the lookouts, the survey techniques were considerably altered for the 1954 project as a result of the 1953 experiences. For the 1954 cloud survey the following preparations were made:

1. A cloud-observation manual was prepared to provide reference material to supplement the school and followup training. The manual

Small Cumulus

Towering Cumulus

Anvil top Cumulus



Virga

Rain

Lightning

Figure 10. In the cloud survey, fire lookouts record the action of cumulus clouds from their initial formation through all advanced stages that occur.

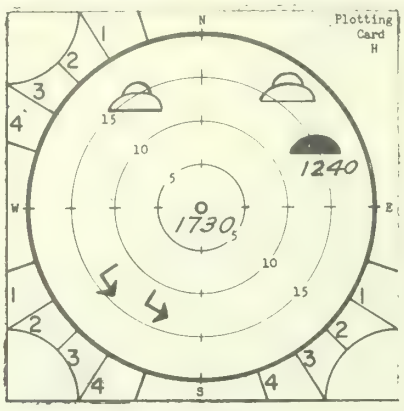
Figure 11. The firefinder used to locate forest fires is also useful in determining the general location of clouds.

described simple techniques for cloud measurements, and discussed the appearance, development, and characteristics of cumulus and upper clouds. It gave photographic examples of the types of middle and high clouds to be identified in the survey.

2. A more detailed operations guide was drawn up, instructing the lookouts in their daily duties.

3. Much of the survey information was put on cards, on which a 1-inch-radius circle represented the area within 20 miles of the mountain summit. Each lookout daily prepared (a) a card showing the first cumulus and the maximum cumulus activity, (b) a card showing all lightning activity, and (c) three cards showing the upper-cloud condition at 0800, 1200, and 1600 M. s. t. (figure 12). Each lookout marked the cards with the same type of pen. The appropriate cards were later affixed to analysis maps (figure 13).

CLOUD SURVEY PLOTTING CARDS



1st Cumulus & Time

Cumulus Area

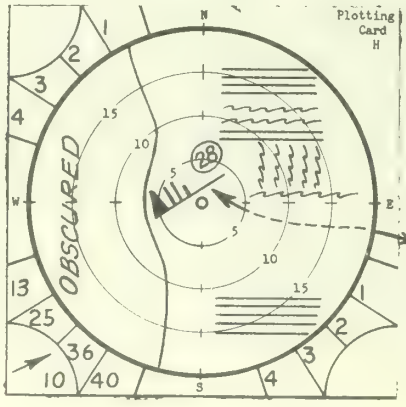
Towering Cumulus

Anvil Tops & Virga

Rain

Thunderstorm

Cumulus Cloud Plotting Card



Cirrus

Cirrocumulus

Altocumulus Billows

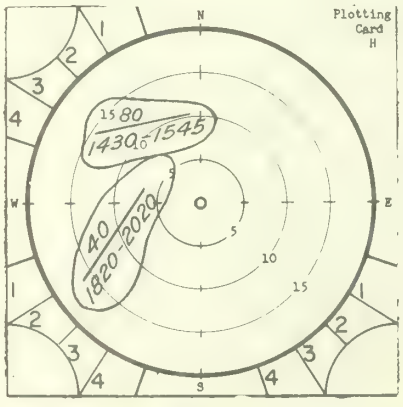
Altocumulus Lenticular

Numbers refer to the four predominant types of upper clouds.

Surface wind velocity and direction.

Indicates velocity & direction of upper clouds. Number above is cloud height in units of 1000 feet.

High and Middle Level Plotting Card



Numerator gives number of strikes.

Denominator gives time.

Enclosed area gives approximate area of strikes.

Lightning Plotting Card

Figure 12. Plotting cards are filled out at lookout stations and are later pasted on analysis maps.

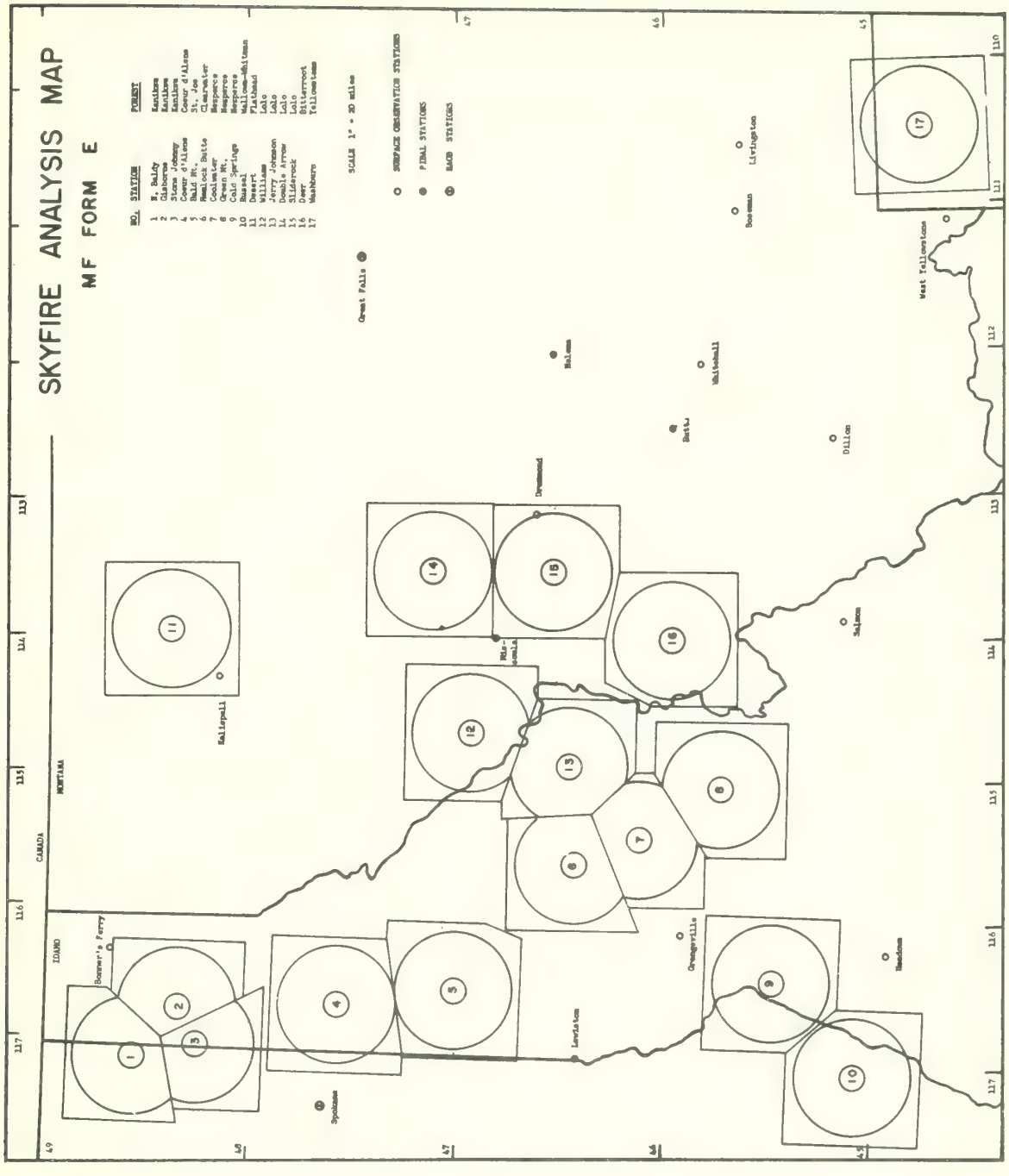


Figure 13. Analysis map on which plotting cards of clouds and lightning are affixed.

4. A form was filled out daily giving details of the information put on the cards, plus a more complete sky picture at 0800, 1200, and 1600 M. s. t., and miscellaneous notes on special happenings (hail, height of cloud tops during precipitation, etc.). Only one form was required per day, and all instructions for the form were given on the front side of the page as shown in figure 14.

5. The upper clouds were divided into 8 varieties of cirrus (ice crystal types), 3 varieties of cirrocumulus (liquid and mixed composition types), 6 varieties of altocumulus (middle level, non-smooth types) and 3 varieties of altocumulus lenticulars (middle level, wave types). The types are clouds common in the Northwest in summer, and include clouds associated with slow-moving air as well as clouds associated with fast-moving air.

6. The velocities of upper clouds were measured at 0800, 1200, and 1600 M. s. t. with an abney level, a watch, and a velocity chart (the cloud elevation had to be estimated).

7. To aid in the measurement of cloud distances and heights, the lookouts were provided with a chart for estimating the height of cumulus cloud bases from surface dry-bulb and wet-bulb temperature measurements, and were given an adjustable scale to use with the abney level for readily relating heights to distances.

8. Every tenth day the lookouts were asked to summarize on the back of the daily form any general comments they had concerning the measuring techniques, cloud-breeding areas, etc.

9. The "flash reports" of 1953, which gave upon demand an instantaneous picture of the sky condition over the survey area, were expanded in 1954 to include a brief radio report from all stations every afternoon (figure 15).

TRAINING CLOUD-SURVEY PERSONNEL

The key people of the Project Skyfire cloud survey are the observers at fire-lookout stations. Most of these observers are temporary employees of the Forest Service who work only during the summer months. They are selected primarily for their ability as observers of forest fires and for their adeptness at living alone on a mountain top. Very few of the lookout firemen have had any previous experience in cloud observation. Therefore, training of the observers in cloud identification and the fundamentals of cloud action is an essential part of the cloud-survey program.

In 1953 and again in 1954 a special 3-day training school was held for all personnel in the cloud-survey network. These schools stressed identification of cumulus clouds, and high- and middle-level clouds. The lookout observers were also given instruction in measuring cloud heights and speeds, use of the firefinder in cloud location,

FORM 6
RF - INT
PREVENTION
Project Skyfire

STATION NUMBER 14
STATION NAME Double Arrow
DATE: DAY 15 MONTH July 1954
OBSERVER Dorothy Taylor

INSTRUCTIONS: ALWAYS FILL IN ALL SPACES, USING A DASH "-" IF NO NUMBER OR LETTER IS APPROPRIATE. USE 0 TO DENOTE SKY CLEAR OF CLOUDS IN THE PARTICULAR CATEGORY. USE 9 TO DENOTE CLOUDS OBSCURED. A WIGGLY LINE UNDER A NUMBER MEANS THE NUMBER IS VERY QUESTIONABLE. CONSIDER 20 MILE RADIUS.

0800, 1200, & 1600 WEATHER RECORD

CUMULUS CONDITIONS

Fill in second and third lines for each observation time, as required by cumulus types and areas.

MOST ADVANCED CUMULUS TYPE: 1 Cumulus, 2 Towering Cu, 3 Anvil tops, 4 Virga, 5 Rain, 6 Thunderstorm
AZIMUTH (DEGREES) TO LEFT EDGE OF CUMULUS OR CUMULUS AREA
ESTIMATED VELOCITY OF CLOUD MOTION (MPH)
DIRECTION FROM WHICH CLOUDS MOVE
AZIMUTH TO RIGHT EDGE. CIRCLE IF AZIMUTHS REFER TO INDIVIDUAL CLOUD
DISTANCE (MILES) TO NEAR EDGE OF CUMULUS

SURFACE CONDITIONS

VELOCITY OF SURFACE WIND (MPH)
DIRECTION FROM WHICH SURFACE WIND BLOWS
WET BULB TEMPERATURE
DRY BULB TEMPERATURE

UPPER CLOUD CONDITIONS

HEIGHT (IN UNITS OF 1000') USED TO FIND VELOCITY. CIRCLE NUMBER IF VELOCITY IS ACCURATELY MEASURED. USE X IF VELOCITY CANNOT BE ESTIMATED.
VELOCITY AT HIGHEST CLOUD LEVEL (MPH)
DIRECTION FROM WHICH CLOUD MOVES

11 Rippled smooth Ci
12 Thin wispy Ci
13 Thick wispy Ci
14 Patterned Ci
15 Hooked Ci
16 Filaments of Ci
17 Coherent Ci
18 Straight bands of Ci
24 Liquid cloudlet Cc
25 Liquid patterned Cc
26 Decaying Cc
31 Patternless Ac
33 Rect. Ac cloudlets
34 Rect. Ac cloudlets with ice streamers
36 Ac billows
37 Coherent Ac billows
38 Ac cloudlets arranged down-wind
45 Standing wave Ac
46 Moving wave Ac
47 Coherent waves of Ac

MST Time	Type	Dir.	Vel.	Az(L)	Az(R)	Dist.	T_d	T_w	Dir.	Vel.	Dir.	Vel.	Height	Ci	Cc	Ac	Acl
0800	2	W	10	250	200	13	70	60	-	0	S	60	20	10	20	38	45
0800							NOTES 0800 & EARLIER										
0800																	
1200	6	W	8	overhead		0	72	61	SE	5	SW	X	30	14	29	39	49
1200							NOTES 0800-1200 Rain NW 6 Mi. at 11:45; first thunder 11:53. Some hail 1205; also light rain.										
1200																	
1600	5	W	10	204	214	12	64	56	N	14	-	-	-	19	29	39	49
1600							NOTES 1200-1600 Rain from another cloud 1313; no lightning. From still another at 1600 at 2100; still no lightning.										
1600																	

LIGHTNING ACTIVITY

TIME OF START (MST)	TIME OF END	NUMBER OF STRIKES	AZIMUTH TO LEFT EDGE OF ACTIVITY	AZIMUTH TO RIGHT EDGE. CIRCLE IF WITHIN 10 MILES
None seen, though thunder heard.				
2200	2314	8	(210)	(120)

SPECIAL ITEMS

Note when and where rain begins. Note if lightning or thunder occurs without any rain. Note any unusual happenings (hail, severe surface wind over 30 mph, much cloud-to-cloud lightning with no strikes, odd motions of vapor trails, etc.). If rain occurs without lightning, try to measure the heights of cloud tops.

TIME	
11:45	Rain began 11:45; at 1208 it was at L.O. with small amount of hail; not much thunder - no cloud to ground strikes. After cloud passed E, took its height when rain was falling on Mt. 10 miles distant. 35,200. (Took color picture including top and rain).
2200	Much cloud-to-cloud lightning, very brilliant near L.O.; dashing rain at 2210 - 2230.

If more space is needed, use the rear of this form. On July 9, 20, 30, August 10, 20, 30, and final day of observations, on the rear write any general notes which you consider helpful (best breeding areas' distances and azimuths, storm courses, observation difficulties, etc.).

Figure 14. Form filled out each day at cloud-survey stations.

Figure 15. Radio communication enables forest-fire lookouts to furnish the Skyfire analysis center with pertinent information on clouds and lightning.

operation of fire-weather stations, and radio-transmission procedures. Much of the training school program was held right at a lookout station where practical cloud-survey operations could be reviewed. Motion pictures and colored slides of clouds were used as aids in cloud-identification training.

Experience has shown that on-the-ground instruction of observers must supplement the more or less formal program of the special training school. Followup training sessions at each lookout station are essential in the development of competent observers. During the fire season some members of the Skyfire staff are continuously engaged in visiting lookout stations in the cloud-survey network. The daily radio reports keep the staff in touch with the lookout observers and often indicate the stations where additional training is most needed. Followup visits to lookout stations also are important in maintaining the teamwork and esprit de corps so important in an undertaking of this nature.

CLOUD ANALYSIS

The compilation of cloud-survey data is a means to an end, not an end in itself. For value, the observations must be related to larger scale synoptic situations. In 1953 a rough first attempt was made to "type" or explain the weather patterns causing lightning. In 1954 the U. S. Weather Brueau provided personnel and facilities for improving the analysis. This phase of the cloud survey is a most important one, and will be receiving a larger percentage of the research effort as Project Skyfire continues.

TIME-LAPSE PHOTOGRAPHY

The system of time-lapse motion-picture photography developed by the Munitalp Foundation provides an excellent means of studying cloud action. In most Project Skyfire operations 16-millimeter cloud photographs are taken at 2-second intervals and then projected at normal speed. This speeds up the motions in clouds about thirtyfold so that an hour of action can be displayed in approximately two minutes of film-projection time. The time-lapse principle enables dynamic cloud action to be seen in a manner not possible with the naked eye. The cloud factors associated with many different weather situations and many types of lightning storms can be recorded on film for detailed analysis.

The equipment used in the time-lapse-photography program is rugged enough for continuous field use and simple enough to operate to insure good results from relatively untrained photographers (figure 16). The automatic-shutter operation on a standard 16-millimeter motion-picture camera is accomplished by a relay which is actuated at the relaxation time of a capacitor-relay circuit. Power is provided by a 45-volt B battery. The camera is mounted on a sturdy tripod (figure 17). Other equipment used in the photography program includes an exposure meter, a protractor for measuring camera angle, and a title board for labeling essential data on each roll of film. Color film has been used for virtually all of the photography.

During the fire seasons of 1952, 1953, and 1954 over 6000 feet of time-lapse motion pictures have been obtained from 12 stations in the northern Rockies. Usually there have been at least four time-lapse motion-picture cameras operating simultaneously during interesting meteorological situations. As a result, regional storms can be photographed to show variations by location and time. The photography of clouds associated with the jet stream has provided an excellent means for studying the motions and shapes of high- and middle-level clouds. Time-lapse photography has been found to aid in detecting the areas where cumulus clouds first form and grow.

Figure 16. The Munitalp time-lapse motion-picture equipment used at fire-lookout stations for cloud photography.

Figure 17. Time-lapse motion-picture cameras mounted on the catwalk of forest-fire lookout stations are in an ideal position to record the life cycle of clouds and lightning.

An important phase of the time-lapse photography program is the use of a "sphere" camera for detailed studies of cloud-breeding areas. This camera photographs the sky through a standard, inexpensive, spherical flask filled with water. The system enables 112° of sky to be photographed from a fixed position of the camera. During 1953 the "sphere" camera was used at Gisborne Mountain in the Priest River Experimental Forest (figure 9). In 1954 the camera was used at Cold Springs Lookout in the Nezperce National Forest to photograph the day-by-day life cycle of clouds which form in the adjacent Wallowa Mountains (figure 9).

The results of the time-lapse photography program show that forest-fire lookout stations are ideal places for the operation of cameras. The commanding view of clouds and mountains and the constant availability of an operator provides about the best possible site for photographic work. A good start has been made on the building of a photographic record of cloud types and action in northern Rocky Mountain skies.

Figure 18. Spectacular clouds, such as these cirrus "streaks," are often associated with the jet stream.

III. STUDY OF THE JET STREAM

The jet stream can best be visualized as a flat, wide, river of air, flowing on a meandering course, generally from west to east, with a central axis of peak velocity winds at 20 to 40 thousand feet above sea level. Observations made to date indicate that one or more jet streams are usually present during the fire-season months either over the northern Rocky Mountain region or just north or south of the area.

Many unknown facts about jet streams remain to be discovered. However, from the information now available, it is clear that any research of lightning and associated atmospheric factors must consider possible relationships to the location and character of jet streams. There is strong evidence that certain high- and middle-level clouds are frequently associated with a jet stream (figure 18). There are also indications that important relationships may exist between a jet stream and the character of lightning storms, as well as the general character of the pre- and post-storm weather influencing the behavior of lightning fires. The jet stream means a strong vertical wind shear, which may tend to blow the tops off towering cumulus clouds and thus hinder them from reaching lightning-storm proportions. In other situations the jet stream appears to make the storm worse.

IDENTIFICATION OF THE JET STREAM WITH CLOUDS

The best way to determine the location of the jet stream by clouds is to note the velocity of airflow as evidenced by cloud motions. This is impossible to do from moving aircraft and difficult from the ground. A second technique is to watch for certain cloud types; forms of cirrus, cirrocumulus, altocumulus lenticulars, and altocumulus billows tend to be associated with the jet stream (13, 14). These 4 types were recorded by the 25 lookout observers in Project Skyfire in July and August of 1953 (figure 19). Direction of cloud motion, cloud velocity, coherence, and surface winds were also noted hourly, and during each observation a rough picture of the cloud positions was sketched. All the data compiled by the lookouts were plotted on area maps for 0800 and 1400 M. s. t. daily, and compared with the position of the jet stream as derived from the U. S. Weather Bureau 300 mb. and 500 mb. charts.

During the 124 observation times of summer 1953, the jet stream was within the region 67 times, and outside or missing 57 times. The following results were obtained:

Jet Stream Present	Ci, Cc, Acl, or Acb Clouds Present	Percent of Instances
No	No	31
Yes	Yes	30
Yes	No	16
No	Yes	23

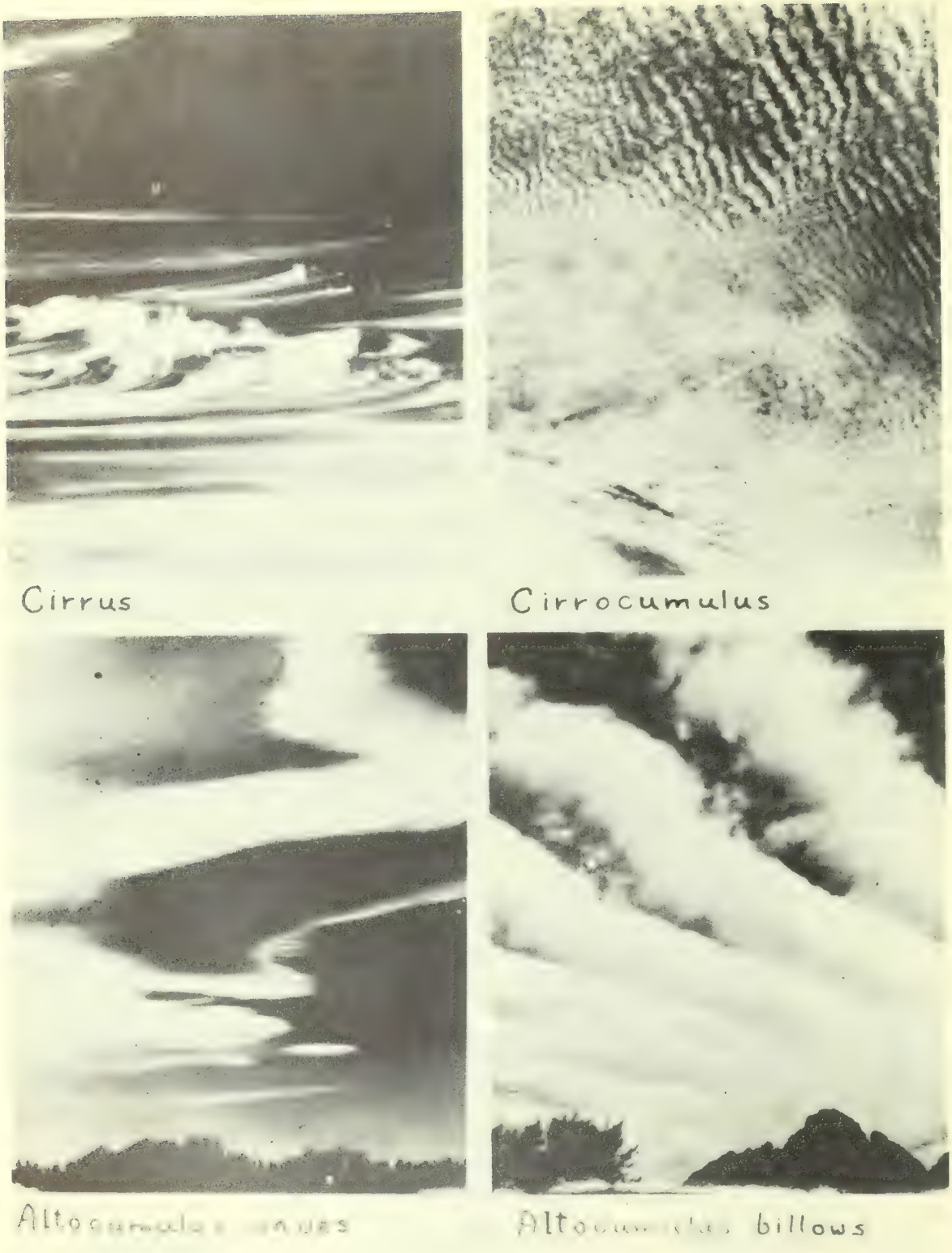


Figure 19. Four high- and middle-level cloud types often associated with the jet stream.

There was no very definite tendency for the clouds to appear on the north side of the jet stream instead of the south, or vice versa.

In 61 percent of the cases the special cloud-association method was successful; no clouds = no jet stream, clouds = jet stream. In 16 percent of the cases the jet stream was present but the air aloft was so dry that there were none of the upper clouds present. In 23 percent of the instances (mostly from August) there was no jet stream but the "associated clouds" (usually several types) were observed. These "failures" may be inherent in the system, but certain other factors certainly contribute to them:

1. The U. S. Weather Bureau 300 mb. network is so sparse that jet stream flows could be present but unobserved on the charts. This might explain some cases, but not many.

2. During the first summer of Skyfire field observations much of the data were not complete and also many bits of evidence had to be discarded due to ambiguity. False cirrus from thunderstorm anvils were undoubtedly often reported as cirrus indicating the jet stream.

3. In most cases of "clouds but no jet stream" there was a low-pressure center about 900 miles off the United States-Canada border, bringing in moist air aloft from the southwest. Slight vertical motions would form clouds in such air. Half of the "clouds but no jet stream" cases were associated with surface or upper fronts, where extra lifting would be expected.

4. The slow-moving clouds were often reported in the diverging-fan area where a jet stream slowed down and lost its identity, or in the corresponding converging area; also they were observed in the slow-moving air close to closed lows with high winds. In many of these cases, although the air in which the clouds existed was slow moving, it had probably been recently in a true jet stream.

5. The mere presence of high- and middle-level clouds is not uniquely related to the jet stream, since moisture and lifting derive from many causes. During the lookout-training course little stress was laid on separating the "fast-looking" clouds from the "slow-looking" type; in fact, only illustrations of the "fast-looking" types were shown. This omission was probably the biggest factor in the "clouds but no jet stream" cases.

During the summer, clouds indicated the jet stream 65 percent of the time it was present. If the additional cases of "clouds but no jet stream" can be avoided by more careful examination of the detailed cloud structure, the whole scheme of jet-stream location by cloud observations can be termed successful. During the winter in this area when the jet stream is twice as fast as during the summer, and in other regions of consistently greater jet-stream speeds, the cloud-identification method should prove even more useful.

ESTIMATING WIND VELOCITY BY CLOUD APPEARANCE

Schaefer has indicated how fast-moving cirrus, cirrocumulus, altocumulus lenticular, and altocumulus billows tend to be the clouds associated with the jet stream (14). Analysis of the cloud-survey data has shown that a further refinement or typing might be employed in order to make location of the jet stream easier from cloud observation: the cloud types should be subdivided into those indicative of high velocity and those indicative of low velocity. Since the cloud texture or microstructure is somewhat independent of air-mass moisture, it will provide a better jet-stream indicator than will merely the presence of certain clouds.

The study of heated fluids in the laboratory, of air currents over the ocean, of alto-level clouds, of wind over sand, and of other natural phenomena has shown a tendency for (1) very small shear to be associated with regular rectangular or hexagonal flow patterns, (2) moderate shear to be associated with transverse waves, (3) strong shear to be associated with longitudinal waves or rolls, and (4) very severe shear to be associated with turbulence, no regular flow. Therefore, the characteristics of certain cirro and alto clouds in jet-stream conditions would be expected to indicate wind shear, and vice versa. Wind shear is related to total wind velocity and is ordinarily in the same direction.

Approximately 60 color and 150 black and white cloud pictures were taken between July 1 and October 1, and compared with cloud velocities measured by the abney-level method. In the preliminary analysis, it was found that cirrus clouds were observed, alone, at 90 knots and 7 knots, altocumulus billows were found between 90 knots and 25 knots, cirrocumulus were present at 70 knots to 20 knots, and altocumulus lenticulars appeared moving 85 knots as well as 25 knots. The combination of any 2 or more of the 4 types likewise did not prove to correlate especially well with velocity.

When a speed factor was given to the appearance of the clouds in each photograph, the correlation with velocity improved greatly. The cirrus were fast moving when they were drawn out into long lines parallel to the wind, by wind shear. They were slow when their structure was weak and random, showing no preferred direction. Of the cirrocumulus, the clouds with the most definite wavelet patterns were the fastest. The fastest altocumulus types were those with pronounced orientation of the cloudlets, either parallel or perpendicular to the wind. The shapes of altocumulus lenticulars depend mostly on ground configuration and so would not be strongly related to wind speeds, but the waves produced by the fastest winds tend to have the sharpest edges and the smoothest texture.

The speed factors were considered when the cloud types for the 1954 lookout training school were established. In effect, each of the four main categories was subdivided into types representative of

different speed ranges; the typing involved elongation, microstructure (or texture), and composition as well as the ordinary cloud-type considerations. The rules can certainly be improved with time, and still be simple enough to be of practical value even for the weak jet streams in the summer in this area.

SURFACE WINDS AND THE JET STREAM

With the small amount of data available it is difficult to generalize on the relationship between surface winds and the jet stream. The mountain winds due to convective heating, the local downdraft outflow of the thunderstorms, and frontal winds may all exceed 25 knots. On the other hand, surface winds below the jet stream may sometimes be very light. However, surface winds greater than 35 knots over an extended distance seem due solely to a jet-stream effect. These winds are doubly dangerous from the fire-danger standpoint because they may occur in dry weather.

During the morning of August 24, 1953, the wind at Salmon Mountain Lookout reached 70 knots; this was directly below the axis of a 70-knot jet stream and in a cold front occlusion situation. Snow, sleet and hail were also reported. The 300 mb. and 500 mb. U. S. Weather Bureau maps showed the velocity was roughly the same at those two levels. This was the maximum wind reported during the cloud survey.

Few of the cloud-survey stations regularly reported the surface winds. The small amount of data available for 0800 and 1400 M. s. t. did show that winds over 25 m. p. h. were almost invariably associated with a jet-stream condition. The 1700 M. s. t. winds were also checked daily at three stations. The maximum 1700 winds, 29 to 43 m. p. h., were recorded on 5 days; a jet stream was overhead 4 of these days, and a frontal situation existed the other day.

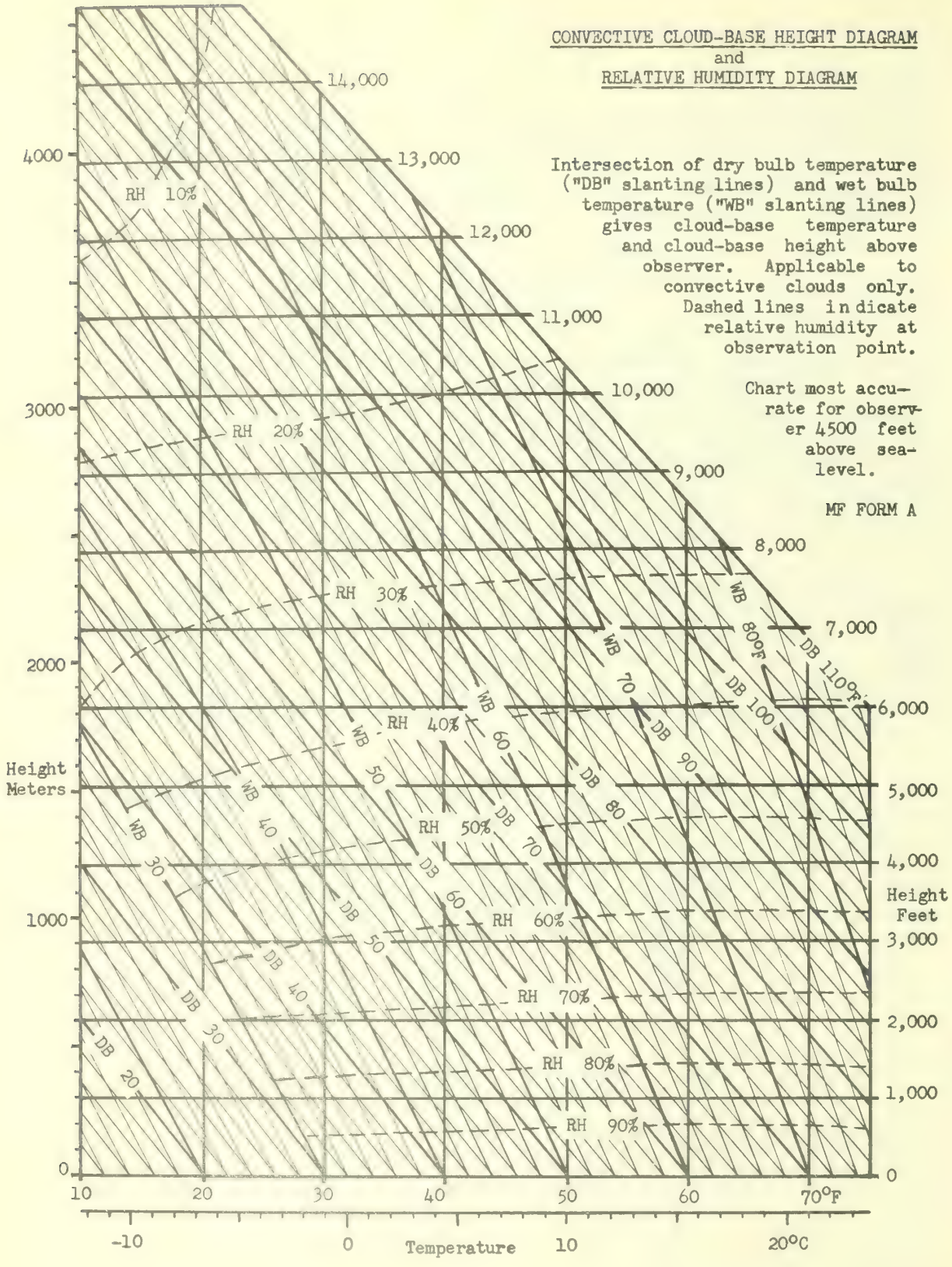


Figure 20. Diagram used in calculating cloud-base height.

IV. SPECIAL STUDIES

The research program of Project Skyfire has called for the development of special tools and research techniques. Also there has been a need to explore the theory of cloud development, the lightning mechanism, and atmospheric electricity. These studies facilitate the general aims of the over-all project. For convenience in reporting they are grouped under the heading of special studies.

WEATHER TYPES AND LIGHTNING

All lightning occurrences in the survey area during July and August 1953, were examined to ascertain the corresponding synoptic pictures. In 1953 there was more lightning than average and there were more frontal passages.

Four frontal weather types were considered, and three air-mass types. The division of lightning storms into types is not simple, since a specific instance rarely fits into one type. Frontal types are differentiated from air-mass types by consideration of whether the vertical motions were mechanically or thermally induced, and yet the activity of fronts does depend strongly on thermal instability and diurnal timing, and the instability of an air mass is strongly affected by the advection of cold air aloft. Understanding the synoptic situation corresponding to lightning occurrences is an important phase of future Project Skyfire work; this preliminary typing served to point out the problems and permit a few generalizations to be made.

There were 15 frontal cases and 13 air-mass cases producing lightning in the summer of 1953. On probably only three occasions did storms begin without surface air reaching the clouds. Therefore cloud seeding with ground generators might affect a large majority of the storms.

CONVECTIVE CLOUD-BASE HEIGHT FROM DRY-BULB -- WET-BULB TEMPERATURES

It is possible to get a rough estimate of the elevation of the base of a convective cloud by measuring the dry- and wet-bulb air temperatures at ground level. Figure 20, MF Form A, permits these rapid height calculations, and at the same time gives the cloud-base temperature and the relative humidity of the surface air. This chart is based on the assumption that the cloud base is the same as the "lifting condensation level," i.e., the level at which condensation begins in the dry, adiabatically lifted air parcel.

If the air parcel that is sampled has the same properties as the air that is forming the cloud, accuracy will be good. In hilly terrain the cumulus clouds tend to form from air heated over the hills; thus a fire lookout is in a good position to sample appropriate air to find the height of cloud bases near the lookout station.

If the moisture content of the air on hilltops and in valleys is the same, the extra heating of the hills will result in higher cloud bases than those bases due to valley air. Experiments have verified this effect; bases as calculated from Gisborne Mountain Lookout averaged about 1400 feet higher than bases calculated from the Priest River Experimental Forest headquarters (3140 feet below Gisborne Mountain Lookout). Presumably the higher bases were the more correct. An obvious rule to correct valley readings to hilltop conditions would therefore be to add, to the valley-calculated cloud height, one-half of the height of appropriate hills above the valley. Many factors contribute to the valley-hilltop differences and so such a simple correction can be but a rough first approximation. The elevations of cloud bases differ over a region and even from cloud to cloud. Glider pilot reports verify that the higher bases are associated with the stronger upcurrents obtaining their energies from mountain heating.

At the Priest River Experimental Forest during a warm mid-afternoon, consecutive temperature measurements at 8-minute intervals yielded cloud-base heights of 8350, 9000, 9280, 8550, 8900, 8970, 8700, 8900, and 9120 feet above ground; these values illustrate how local conditions change rapidly, and demonstrate some of the inaccuracies of the method. They show why there is no need to read the temperatures more accurately than to the nearest degree.

The dry-bulb and wet-bulb measurements may conveniently be taken with a small sling psychrometer. Tests with this device show that 250 swings will bring the temperature readings to within about one-tenth of a degree F. of the true ones.

MF Form A (figure 20) has been compiled by using (a) the change of dewpoint with elevation shown on U. S. Weather Bureau Form 113E, (b) the dry adiabatic lapse rate indicated on Form 1147B (revised December 1950) which differs from that on the older U. S. Weather Bureau Form 1113E, (c) dewpoints and humidities from the table supplied by the U. S. Forest Service for elevations between 3800 and 6000 feet above sea level. This chart is most accurate for observations at 4500 feet above sea level but may be used effectively on all mountains in the Skyfire network.

CLOUD-BREEDING AREAS

A cloud-breeding area may be defined as an area where there is a tendency for cumulus clouds to originate or develop into more advanced stages. To the extent that thunderstorm activity is affected by topography and other surface conditions, one may hope to locate these breeding areas both by theoretical calculation and by cloud observation. Surface effects presumably are more important during the early stages of cumulus development.

Hills help to produce upcurrents for a variety of reasons:

1. Slope Effects:

   a. Mechanical. The orographic effect of wind being forced to blow up the slope helps start the upcurrents, and in addition the mechanically induced upward motion of stable air serves to reduce the air's stability.

   b. Thermal. Since the sun is only rarely overhead, slopes rather than horizontal ground are usually more perpendicular to the sun's rays and thus receive more radiation per unit area. Other considerations being similar, such sloping surfaces would therefore become warmer than horizontal surfaces. In addition, the heat per unit area on slopes is concentrated over a smaller horizontal area; this is important for steep cliffs.

2. Height Effects:

   Air remains in neutral stability if its temperature decreases 5.5° F. per 1000-foot increase of elevation. Although mountaintops are generally cooler than adjacent valleys, they are usually not as much as 5.5° F. cooler per 1000 feet of elevation. Thus they tend to produce thermals more often and of larger size than do adjacent valley areas.

   These effects plus others such as the radiative properties of the vegetation and ground surface and the presence of nearby lakes all vary in importance depending on the meteorological situation. The concept of a breeding area is thus seen to be complicated. In general, however, mountains produce the earliest and also the best thermals.

   The lookout observers collect data on the positions of the first cumulus clouds in their areas. These data have not been analyzed in detail, but they do conform to the above concepts.

   The lookouts have been unanimous in their statements that only rarely do local storms develop out of local small cumulus clouds. Almost invariably the storms move in from another area after they are already well developed. The breeding-area concept is still valid, but the breeding areas may often be far from the regions where the storms produce the damaging lightning.

CLOUD VELOCITY MEASUREMENTS

In addition to providing a convenient tool for calculation of cumulus cloud heights, an abney level calibrated in feet per chain proved to be a useful field instrument for the measurement of upper-cloud velocities (figure 21).

Figure 21. An abney level is a handy tool for calculating cumulus cloud heights and upper-cloud velocities.

The horizontal velocity of cloud elements is almost exactly the air velocity. Even standing wave clouds which have zero velocity contain elements which move with the wind speed; the individual cloud particles cannot be seen from the ground, but a turbulent eddy or cumulus-like puff can almost invariably be seen moving through the larger cloud mass with the speed of the wind.

If the height of the cloud can be estimated, its velocity may be found by measuring its elevation angle and azimuth position at the start and end of a specified time interval. If the cloud motion is directly away from or toward the observer, aximuth remains the same and only elevation need be measured.

During the fire season cloud velocities were estimated with the aid of an abney level, a small, handy, commercially available instrument having more accuracy than needed. The time interval was noted during which a portion of the cloud moved from one elevation angle to another. Elevation angle changes of 80 feet per chain to 60, or 60 to 48, or 48 to 40 all correspond to the same horizontal distances of cloud movement. MF Form D (figure 22) was drawn corresponding to these pre-selected angle changes. It shows velocity in miles per hour for a range of heights and time intervals.

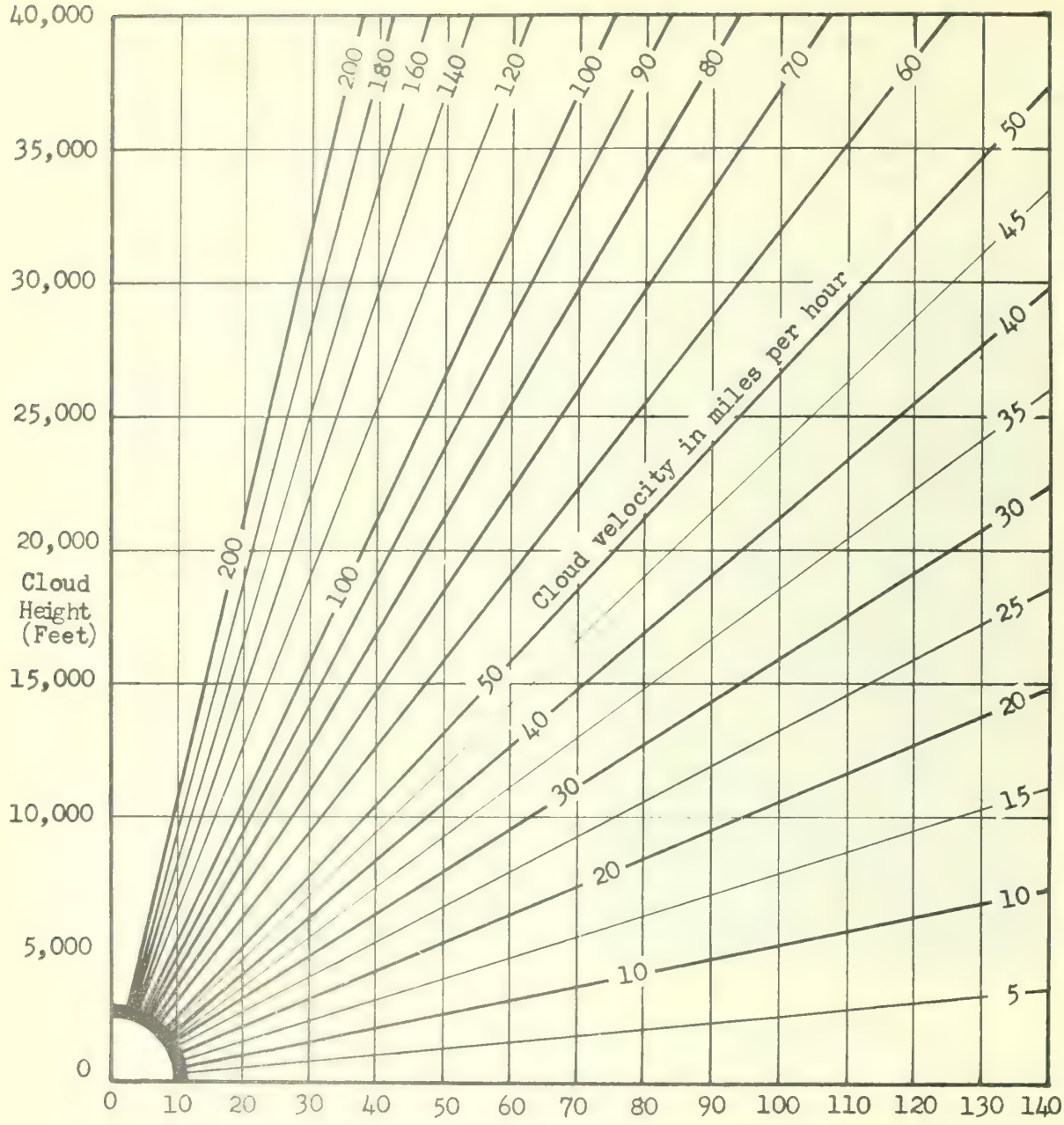
If the abney-level technique is utilized for cumulus cloud movements, cloud-base heights can be estimated from surface dry bulb--wet bulb temperature measurements. Cloud-top heights are obtainable with the level by taking a ratio with known base heights. The heights of alto- and cirro-level clouds can be simply estimated on the basis of past experience with sufficient accuracy. Percentage accuracy of the velocity measurements is practically identical to the percentage accuracy of the cloud-height estimates.

ATMOSPHERIC ELECTRICITY MEASUREMENTS

There is a potential difference of several hundred thousand volts across the insulating lower atmosphere between the more highly conducting ionosphere and the earth. The voltage difference is maintained by thunderstorms. The resulting slight current that flows from air into the ground may be collected on a needle-sharp collector to an extent that it can be measured (6, 16). The corona discharge at the needle point increases the local conductivity of the air to effect this collection. A radioactive-tipped probe ionizes the surrounding air and collects more current than the simple needle point. Such a tip, coated with gold foils impregnated with radium sulfate, was set on the corner of Gisborne Mountain Lookout in the summer of 1953 and the current through it measured hourly on a microammeter to see if the current could be correlated with clouds or the jet stream.

Measurements in the eastern part of the country had shown that the current would be high under both jet-stream and thunderstorm conditions. However, in Idaho the only time when the meter reading could be correlated with the weather picture was when thunderstorms were nearby. These often reverse the sign and increase the current by several orders of magnitude (at which time the meter is disconnected for safety). On other occasions the reading varied between 0.01 and 0.10 microampere, with strong diurnal effect. On a typical day the current will average 0.02 microampere at 0700 P. s. t., reach an average of 0.05 microamp at noon, and drop again to the initial value by 1800. The diurnal variation of the whole earth-to-air gradient structure caused a potential maximum around 1000 P. s. t. (corresponding to maximum thunderstorm activity over the whole world); the variation is only about 15 percent, and cannot account for the needle current readings.

Interpretation of the readings must await further research. Tests are being continued.



Use this chart for finding the velocity of clouds moving directly toward or directly away from the observer. Measure △, the time interval in which the cloud elevation angle changes from 80 feet per chain to 60, or 60 to 48, or 48 to 40 (or the reverse, 40 to 48, 48 to 60, or 60 to 80). At the intersection of △ and the estimated cloud height above the observer, read the cloud velocity. If △ is greater than 140 seconds, use $\frac{1}{2}$ △ and $\frac{1}{2}$ the altitude. For Abney Levels calibrated in degrees, note 80 ft/chain=50.5°, 60 ft/chain=42.3°, 48 ft/chain=36.0°, 40 ft/chain=31.2°.

CLOUD VELOCITY BY ABNEY LEVEL (feet per chain calibration)

Figure 22. Chart used for finding the velocity of clouds with an abney level.

Figure 23. A radioactive-tipped probe for measurement of atmospheric electricity is mounted on the 150-foot meteorological tower at the Priest River Experimental Forest.

NATURAL FREEZING NUCLEI MEASUREMENTS

On 15 days during late August and September of 1953 samples of surface air were checked at several temperatures for the presence of natural freezing nuclei. A portable cold box loaned by Meteorology Research, Inc., was employed for the measurements. In 1947 Schaefer developed the first such portable cold box wherein cold air from dry ice cooled the copper-lined test chamber to the desired temperature. The present unit features a 10-power viewing system and a thermostat-controlled cooling apparatus which is both cooled and powered by the sublimation of dry ice.

The measurement of threshold of freezing nuclei activity varies between -10° C. and -20° C., being most of the time around -13° C.

Counts at -25° C. were from 0.1 to 15 nuclei per cc. of air, with the median being about 2.0 nuclei per cc. On a typical day the counts might be as follows: threshold at -13° C., 0.1 nuclei per cc. at -18° C., 2 nuclei per cc. at -25° C., 10 nuclei per cc. at -38° C.

Except for two instances all the measurements were made during the day in a valley, usually at the Priest River Experimental Forest headquarters. On two occasions the nuclei were counted on North Baldy and Gisborne Lookouts; at these high elevations the nuclei threshold temperatures were lower than the median at low elevations, but not significantly so.

The nuclei measurements were too few to warrant the attempt to correlate them with time of day, synoptic pattern, surface wind, etc. They all do show, however, that silver iodide particles are far more efficient nuclei than the natural ones, and so seeding may be expected to produce results of some nature in this area.

Some information on natural nuclei aloft may be inferred from the appearance of the middle and upper clouds. On various occasions the temperatures of these clouds were estimated from the Spokane radiosonde report and measurements or estimates of the heights of clouds over northern Idaho. There were many cirrus forms, completely glaciated, but there were also numerous examples of liquid cirrocumulus clouds at temperatures between -32° and -40° C., meaning that on many occasions the natural nuclei content at high elevations was extremely low. On the other hand, often altocumulus forms at temperatures in the -10° C. to -20° C. range would develop snow virga, indicating the presence of a fair number of freezing nuclei.

WIDE-ANGLE AND 3-DIMENSIONAL PHOTOGRAPHY

The advantage of wide-angle photographs for almost all cloud photography is obvious. Overlapping photographs, joined together to give a wide-angle panoramic effect, were tried. The inconvenience of this technique initiated the development of some extremely wide-angle-lens cameras, which were first used during the 1954 field season. These inexpensive cameras take an 85-degree picture 2- x 7-inch, on number 120 film (figure 24).

The value of 3-dimensional photography to give both qualitative and quantitative data on cloud forms became apparent. After the 1953 season, stereo pairs were made from consecutive frames from an airborne time-lapse camera. A representative pair of pictures taken from an airplane are shown in figure 25, together with instruction on how they may be viewed without special glasses.

Two sets of stereo cameras have been built for taking photographs of clouds from the ground. One set uses a radio unit to trigger one camera of the pair, the other set effects the synchronization by use of

Figure 24. Wide-angle cloud photo of the type taken each day during the 1954 fire season at the U. S. Forest Service Aerial Fire Depot, Missoula, Montana.

Figure 25. A 3-dimensional photograph pair. These two pictures were taken about a mile apart. If the left one is viewed with the left eye and the right one with the right eye, an exaggerated 3-dimensional effect is produced. Ordinarily such stereo pairs are viewed with a stereo viewer. The viewer is a help, but some people can get the 3-dimensional effect without a viewer. Try this by looking at a distant object, and then moving the pictures in front of your eyes at a distance of a foot or more. Squinting helps greatly.

a timer or by telephone communication between two operators. A photo analyzer has been constructed to simplify the obtaining of accurate heights and distances from the resulting negatives.

Time-lapse movies taken from a fixed point show the development of clouds; on the other hand, time-lapse movies taken from a fast-moving aircraft give an almost instantaneous "3-D" picture of cloud situations. The Boeing Airplane Company has used a time-lapse camera from extremely high-flying aircraft moving over or near the Project Skyfire region. When these pictures are projected at normal speed, the time-scale speed-up makes them appear to have been taken from an airplane or rocket moving about 8000 m. p. h. This apparent rapid motion gives a strong 3-dimensional effect to the pictures, the effect being due to the difference of relative motion between near and distant clouds.

PRECIPITATION MECHANISMS

To date, Project Skyfire has not attempted systematic study of precipitation mechanisms; in fact, special equipment has not been available to help with such a study. However, some ideas can be inferred from visual observations.

Presumably both the ice-crystal mechanism and the water-drop mechanism (at temperatures both above and below freezing) are simultaneously active in towering cumulus or anvil-topped clouds--the vital problem of the relative importance of the two distinct mechanisms has not been resolved. On August 20, 1953, at the Priest River Experimental Forest, the measured tops of cumulus clouds producing showers were definitely warmer than -5° C., and many were estimated to be above freezing. At the same time and area, measurement of natural freezing nuclei indicated no nuclei were effective at temperatures as warm as -11° C. No glaciation was visible in these clouds. Presumably the water-drop mechanism was producing all the precipitation in this case. Various fire lookouts reported that showers without glaciation were common from large cumulus clouds; probably a sizable share of the water reaching the ground in the summer in this region never goes through an ice phase.

It is quite conceivable that the water-drop mechanism may still be a major cause of precipitation in cumulus clouds which have ice anvil tops.

V. METEOROLOGICAL APPROACHES TO REDUCTION OF FIRE DANGER

There are several ways in which weather modification could decrease fire danger. For example, if extra rain can be induced to fall on an area, the chance of a fire starting there will be reduced and the growth of an existing fire will be inhibited. Even an increase of humidity near the ground will tend toward similar effects. The method of fire-danger reduction by increasing precipitation could help with man-caused fires as well as lightning fires. Another approach is to try to decrease the amount of lightning, either by altering the development of thunderstorm clouds, or altering their electrical characteristics. The results of cloud-seeding experiments suggest that one or more of the above approaches will someday reduce the lightning problem. Numerous possible seeding techniques suggest themselves, but much more research needs to be done before any method can be applied in a practical and economical manner. The data being gathered in cloud surveys should provide part of the essential background for future seeding experiments.

REGIONWIDE SEEDING

It may be feasible to seed an entire region for a net precipitation increase, even though the precipitation is uncorrelated with particular fires. Here the danger of floods and the inconvenience which rain causes to commercial interests must be balanced against the possible saving in fire-prevention cost and timber loss. Many projects for regionwide seeding for extra rain have been conducted since 1950. The few published results (4, 5, 8, 9, 11) are in general encouraging but still controversial. Some results seem good, some bad, and so far most are inconclusive. The many unpublished results are similarly encouraging but likewise confusing. Most of the projects stressed ground generators emitting silver iodide smoke. The detailed modes of operation differed considerably.

LOCALIZED SEEDING

Seeding of a specific cloud or local area, which might be employed to help extinguish an existing fire, is better substantiated and is not influenced by the same possible negative economic considerations as is regionwide seeding (12). Dry ice and silver iodide are conventionally employed. In some cases, a forest fire itself helps cause the buildup of a cloud over it from which rain may fall or be induced to fall.

INHIBITING CLOUD BUILDUPS

It is universally agreed that cloud-to-ground lightning strikes require large, convective-type clouds. Therefore any seeding which would prevent such large clouds from forming would inhibit lightning, no matter what final mechanism causes lightning. The most prevalent theories of lightning formation are concerned with some interaction of ice and supercooled water, so it is well to consider what steps could cause modification of electric fields produced by this mechanism. However, the size and energy magnitudes of thunderstorms are so tremendous that control can perhaps only be effected by seeding to prevent large-cloud formations instead of seeding to alter the final form.

The evidence, often contradictory which is available to show how cloud seeding might inhibit the growth of cumulus clouds, is too involved to treat here, but a few points are worth mentioning.

The major source of energy for thunderstorm development comes from the release of latent heat as water vapor condenses into cloud droplets. There is no rule that a certain amount of energy must be utilized by the clouds on a certain afternoon; if one cloud can be inhibited by seeding, it does not "feed" on as much energy as would otherwise be the case. Its lack of growth does not necessarily make more energy available to other clouds--in fact, it may make less energy available to the other clouds. There may thus be a chain effect--inhibiting one cloud may help inhibit later ones. These concepts give one the hope that some sort of seeding can be employed to alter the weather during a whole day over a large area.

When precipitation begins in a cloud, decay sets in rapidly. If dry ice, silver iodide, or sodium chloride seeding were to initiate precipitation earlier than natural conditions, the sizes of clouds could presumably be kept smaller than usual. Since silver iodide or dry ice adds some heat energy to a cloud (by releasing the heat of fusion of water as the supercooled cloud shifts to the ice crystal phase) the cloud may become more stirred up than usual, entrain more dry outside air, cool by evaporation, and decay earlier. Seeding may produce many other effects which negate these actions, but the possibilities do exist of using these mechanisms to inhibit cloud growth.

CHANGING THE ELECTRICAL STRUCTURE OF CLOUDS

It is difficult to decide how to try to alter the characteristics of lightning because as yet there is no one accepted theory as to how lightning originates. Reference (7) includes a comprehensive review of the major lightning mechanisms which have been proposed. Newer reviews will soon be available. The most popular ideas now concern the coexistence of ice and supercooled water. Thus an obvious approach to preventing the buildup of electrical charges is to reduce the amount of supercooled water in a cloud, by overseeding with dry ice or silver iodide. A difficulty with this method is that there are physical limitations to the amount of seeding material which can be put out and effectively distributed within the cloud mass. In addition, if one area is overseeded and a nearby area unseeded, there must be intermediate regions of all other degrees of seeding--and in some of these areas the seeding may produce an unwanted effect.

Some experiments have pointed out the possibility that charge generation may be very dependent on the slight impurities in the water which constitutes a cloud. Tests which simulated cloud conditions implied that the sign of the charge could be changed by changing the type of impurity. Ammonium salts gave a sign opposite to that ordinarily found in the atmosphere. Actual seeding with ammonia did seem to be associated with unusual electrical happenings in the clouds, but the results are merely suggestive of a possible approach to further research.

If a good electrical conductor were placed vertically in a thunderstorm cloud, the charges being generated would presumably discharge through it and neutralize themselves to nondangerous values. Similarly, if the conductor went from earth to the bottom charge center of a cloud, lightning to the ground would be eliminated. A wire would be an effective but impractical conductor for this job. Air ionized by radioactivity could conceivably offer some hope.

The very active and extensive researches of thunderstorms now underway both in the United States and in other countries lead one to believe that much new knowledge in this field will become available within the next few years. It is important that personnel active in Project Skyfire remain in close contact with the advance in knowledge along such lines since it is quite possible that the kind and nature of the field observations being made by Skyfire may be of considerable value in supporting or discounting some of the new ideas advanced in this field of research.

VI. THE JOB AHEAD

The first results of Project Skyfire demonstrate the possibilities of using forest-fire lookout stations for cloud-survey purposes. Continued attention must be given to the development of observational procedures which will permit relatively untrained personnel to obtain useful meteorological information. If it can be demonstrated that this method is practical and useful an extremely important contribution to forest-fire and meteorological field research will be achieved.

If significant progress is to be made in the understanding of dynamic weather processes and lightning fires it is of great importance that both the meteorologist and the forester have adequate field observations available. The development of such procedures is one of the major objectives of Project Skyfire. If successful, it will result in the establishment of a new approach to field research procedures and will tap a tremendous potential for the widespread recording of what may be termed the microstructure of regional cloud systems. By these procedures it should be possible to detect the genesis of storms which become dominant in the development of weather patterns or which lead to serious lightning-fire occurrences. In this manner it may be possible to determine the various forms which natural storms assume and thus establish the patterns which may be expected under different atmospheric conditions. Such results will not be achieved quickly or easily. However it may be expected that this approach, if successful, will be an important step forward in meteorological science and in forestry.

By concentrating the efforts of Project Skyfire toward the understanding of thunderstorm patterns and types in the northwestern mountains, a subject has been selected having great scientific and economic value. If it is feasible to establish the variabilities of natural storms it should be possible to detect effects produced by cloud-seeding procedures. In seeking this goal many other important findings should be made along the way.

By using the Munitalp-University of Washington-Forest Service mobile weather observatory (figure 26) and time-lapse and stereophotographic recording techniques under various atmospheric conditions a number of new meteorological parameters will be measured and correlated for the first time. Simultaneous measurements of such factors as the concentration of condensation and ice crystal nuclei and atmospheric electricity together with the more standard weather measurements correlated with observed cloud forms and patterns may establish some of the complex interrelationships which combine to produce variations in fire-weather patterns. Much exploratory work is needed in this approach to the chemistry and physics of the atmosphere. The observational procedures which will be established as field experience is gained should be of considerable value in this relatively new phase of meteorology.

Figure 26. The mobile meteorological laboratory can measure and record many atmospheric factors related to lightning fires.

It is of primary importance that the field results of the Skyfire observational program be reduced to useful information. The cloud survey has already resulted in the accumulation of a considerable mass of data. While a certain quantity of these data are useful, their greatest value to the research program was the field experience which permitted the development of the considerably improved procedures now adopted for use. By having a special research meteorologist active during the 1954 season, by depending on the mountain-summit observers to prepare plotting cards, and by getting daily cloud observations by radio relay, much of the results of the observational program will be analyzed or at least plotted on a day-by-day- schedule. This should greatly reduce the task of analysis after the end of the fire season.

In 1954 the program has produced a valuable collection of meteorological data. This is now available for many studies ranging from analysis of the air motions in a jet stream to the relationship of jet streams to surface winds, and lightning storms and fires to fire-weather conditions.

The cloud survey has produced observational techniques for worldwide use wherever similar facilities are available. From experience now obtained it is planned to complete and print the cloud-observation manual used experimentally at all lookouts preparing daily reports in 1954. The next logical step in the lightning-storm and jet-stream cloud studies would be the establishment of a more extensive mountain-summit observational network, based on the Skyfire cloud manual and observational procedures. It may now be possible to study lightning fires in the western United States from the northern Rockies to California.

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APPENDIX

"The Use of Clouds for Locating the Jet Stream" by Vincent J. Schaefer. Reprinted with the special permission of the Editors and Publishers of "The Aeroplane."

Reprinted from "The Aeroplane," October 30, 1953

The Use of Clouds for Locating the Jet Stream

In this article MR. VINCENT J. SCHAEFER, *who is scientific adviser to the Munitalp Foundation Inc., of Connecticut, U.S.A., discusses the possibility of identifying the location and path of the high-velocity winds known as "jet-streams". The article is illustrated by coloured photographs taken by the author.*

As air traffic increases and aeroplanes are built to go faster and higher, knowledge about the properties and characteristics of the atmosphere between 0,000 and 50,000 ft. becomes of increasing importance. mong the interesting features of this portion of the mosphere are the high-velocity winds which flow in latively narrow streams through the middle latitudes an ever-changing and meandering pattern. These are ie so-called "jet-streams" and "jet-streaks" which old great interest to the meteorologist and climatologist well as the persons who must operate aircraft in such gions of the sky.

These high-velocity air currents which encircle the earth and have a mean west to east movement in both the northern and southern hemispheres are being studied by a rapidly increasing number of scientists. It is not uncommon to have two, and even three, major jets with six or more minor ones passing over North America at one time. Their cross-sectional width ranges from fifty to several hundred miles with velocities from sixty to two hundred or more knots. As might be expected, the higher velocities tend to occur when the streams are narrow in width and thickness. The importance of obtaining a more adequate knowledge of this phenomenon is obvious to those who fly aircraft.

Beginning about 1943, the writer started observing and

Top left, bands of thin lenticular below cirrocumulus patches; flow from horizon toward camera. Top right, cirrus patches and bands at high altitude with flow from left to right. Left, cirrus waves under conditions featured by rapid changes and flow from lower left to upper right. Right, sunrise appearance of thin cirrocumulus with altocumulus near far horizon; flow toward horizon

photographing spectacular cloud patterns which appeared from time to time in eastern New York. One of the most noticeable features of these cloud forms was their rapid motion through the sky, easily observed despite their high altitude. The direction of cloud motion was seen to vary from north-east through west to south with most cases ranging from north-west to south-west. The clouds often appeared with a leading edge that was quite spectacular, giving evidence of very high velocity and extreme turbulence.

Early in 1952 when 200 and 500 mb charts showing the wind field over the United States became available for

Edge of cirrus shield stretching from New York to Nova Scotia. Flow from lower right toward upper left.

study, the writer soon discovered that these unusual cloud patterns were closely related to the major axis of the jet-stream.* These studies showed that the major axis of the jet-stream is closely related to the formation of four easily identified cloud types. Typical examples are shown in the accompanying illustrations. They consist of:—

(i) Lines of cirrus clouds in bands, streamers or sheaves;

(ii) Patches of cirrocumulus and two forms of altocumulus;

(iii) The distinctive lenticular forms in either standing or travelling waves; and

(iv) Waves or billows covering localized portions of the sky.

* Schaefer, V. J.: "Clouds of the Jet Stream." *Tellus*, April, 1953. Stockholm.

These clouds are as easily recognized from the air as from the ground when the aircraft is underneath the clouds. Whether this will also be true from above is not yet known, although the writer is inclined to believe that they will be as easily recognized from above as from below.

Several hundred observations were made by the writer during the past year, mostly in the United States, but to a limited extent in Great Britain, Scandinavia and Switzerland. As a simple rule for establishing the close proximity of the major axis of the jet-stream the following conditions have now become fairly well established:—

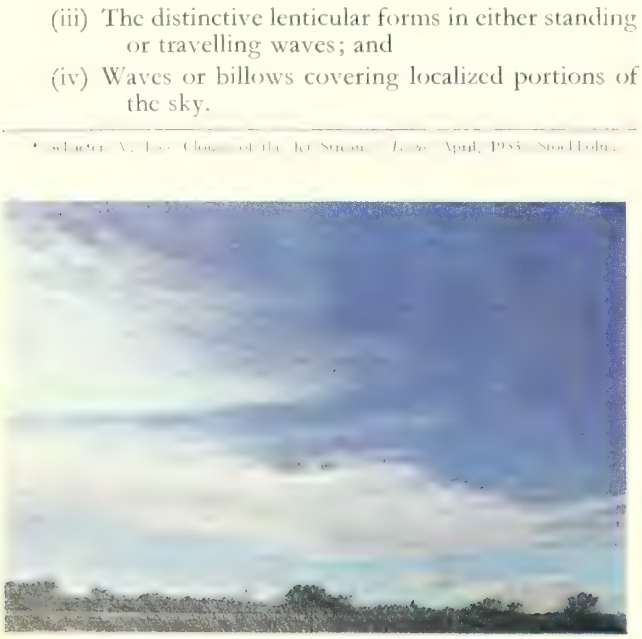
(i) At least three of the four cloud forms should be seen within a period of several hours.

(ii) The clouds must be part of a coherent pattern across the sky.

(iii) They must show evidence of high velocity of movement and rapid changes in structural details.

The rate of motion is easily established from the ground by observing the relative motion of the clouds past some reference point. From a moving aircraft this is more difficult. Under such conditions the rapid changes in structural detail may be used since this is related to the high velocity of movement of the clouds.

In most cases thus far observed when the major axis of the jet-stream in the 500—300 mb levels was overhead, the sky on the left side major axis looking downwind was cloudless with cool, dry air and unlimited visibility while the sky to the right often exhibited increased cloudiness.



Left, line of high banded cirrus with flow from upper left to lower right. Right, ripples developing in high cirrus with billows at right-angles to flow in direction from left to right. Above right, very high altocumulus lenticular with trails of ice crystals downwind.

Above, high altocumulus lenticular waves having many layers and shedding ice crystals downwind from right to left.

Nearly 1,000 ft. of time-lapse motion pictures have been obtained during the past year by the writer while engaged with the Munitalp Foundation's Atmospheric Research Project. These show many interesting features, particularly of the relative air motions which are an integral part of the air flow. By studying the relative mass motions of the ice crystals or supercooled water droplets which form the thin clouds mentioned previously, it should be possible to obtain a better understanding of turbulence encountered in regions in and near the jet-stream. Preliminary studies of the time-lapse movies disclose many examples which must represent turbulence. Flights in such clouds synchronized with time-lapse movies should provide valuable data on this important phenomenon.

There are a number of problems related to jet-stream clouds which need further attention. These include the following:—

(i) If it is true that specific cloud forms mark the major axis of the jet-stream how feasible is it to use this knowledge in planning a more efficient flight plan ?

(ii) Do these clouds mark the location of the fastest winds or are they just part of a broad, even flow of air ?

(iii) What types of clouds have bad turbulence and what types are free from turbulence ?

(iv) Is it better to fly in, above or below jet-stream clouds to obtain the most effective use of its high velocity ?

Above left, large and small ripples and high cirrus, with flow from upper left to lower right. Above, high cirrus, forming billows—oriented in various directions with respect to direction of flow, from upper left to lower right; clouds rapidly changing in appearance.

By observing condensation trails formed in and near jet-stream clouds the writer is of the opinion that certain types of clouds mark regions of extremely smooth air while others will be violently turbulent. Some of them show large-scale shear and circular vortices while others show remarkable standing and travelling waves of great magnitude and velocity.

Top, combination of high thin cirrus with veil of lower clouds consisting of altocumulus lenticular and billow forms; flow from lower left horizon to upper right. Lower picture shows high cirrus in lines with long direction indicating jet flow from lower left to upper

Left, elongated patch of cirrocumulus looking in direction of flow which is toward horizon. Right, series of altocumulus billows. Flow toward horizon.

A number of the problems which require answers may be obtained with a minimum of additional effort. Keen observations aided by simple photography will add much important information to this interesting problem, viz., are jet-stream clouds useful to the aviator while in the air or will they be more useful to the meteorologist in supplementing his scant RAWIN† and PIBAL‡ observational programme from the ground.

With the possible exception of the hurricane or typhoon and the thunderstorm, there are few cloud structures of more interest, greater beauty or more importance than the clouds of the jet-stream.

† RAWIN.—Combination of the words radio and wind. Radio Sonde equipment is sent up on a balloon and this transmits messages, at various heights, of pressure, temperature, humidity and wind.

‡ PIBAL.—Combination of the words pilot and balloon. A plain balloon is sent up and its course is followed with the aid of a theodolite, from which various readings are taken every few minutes.

Time is not far off when the air liners in the higher latitudes will travel with the sun; when that day (or night comes) the sun will not appear to the passengers to rise or set. Meantime it still overtakes the transatlantic air liner as it did the Sabena DC-6 from which this picture of a sunset high over the Atlantic was taken.